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A SIMPLE SINGLE-ACTING STEAM ENGINE.

THE great bugbear staring the amateur mechanic in the face when he contemplates making a small steam engine is the matter of boring the cylinder. To bore an iron cylinder on a foot lathe is difficult even when the lathe is provided with automatic feed gear, and it is almost impossible with the ordinary light lathe possessed by most amateurs. To bore a brass cylinder is easier, but even this is difficult, and the cylinder, when done, is unsatisfactory on account of the difficulty of adapting a durable piston to it.

The engravings show a simple steam engine, which requires no difficult lathe work; in fact, the whole of the work may be done on a very ordinary foot lathe. The engine is necessarily single-acting, but it is effective nevertheless, being about 1-20 H. P., with suitable steam supply. It is of sufficient size to run a foot lathe, scroll saw, or two or three sewing machines. The cost for materials ought not to cost more than five dollars.

The cylinder and piston are made from mandrel drawn brass tubing, which may be purchased in any desired quantity in New York city. The fittings are mostly of brass, that being an easy metal to work.

The principal dimensions of the engine are as follows:

Cylinder.—Internal diameter, 1 5/16 in.; thickness, 1/8 in.; length, 3 5/8 in.

Piston.—External diameter, 1 5/16 in.; thickness, 1/16 in.; length, 3 1/4 in.

Length of stroke, 2 in.

Crank pin.—Diameter, 1/4 in.; length of bearing surface, 1/8 in.

Connecting rod.—Diameter, 1/16 in.; length between centers, 5 1/2 in.

Shaft.—Diameter, 5/8 in.; diameter of bearings, 1/4 in.; length, 6 in.; distance from bed to center of shaft, 1 1/2 in.

Flywheel.—Diameter, 8 in.; weight, 10 lb.

Valve.—Diameter of chamber, 1/16 in.; length, 1 1/4 in.; width of valve face working over supply port, 1/8 in.; width of space under valve, 3/4 in; length of the same, 1 in.; distance from center of valve spindle to center of eccentric rod pin, 3/4 in.

Ports, supply.—Width, 1/16 in.; length, 1 in. Exhaust.—Width, 1/4 in.; length, 1 in.; space between ports, 1/16 in.

Pipes.—Steam supply, 1/4 in.; exhaust, 3/8 in.

Eccentric.—Stroke, 3/4 in.; diameter, 1 1/16 in.; length of eccentric rod between centers, 8 3/16 in.

Cut-off, 5/8.

Thickness of base plate, 1/4 in.

Wooden base, 6 1/4 in. x 8 in.; 2 3/8 in. thick.

Thickness of plate supporting cylinder, 3/8 in.

Total height of engine, 13 1/4 in.

Distance from base plate to under side of cylinder head, 9 1/4 in.

Diameter of vertical posts, 3/16 in.; distance apart, 3 1/2 in.; length between shoulders, 6 1/4 in.

Base plate fastened to base with 1/4 in. bolts.

The connecting rod, eccentric rod, crank pin, and shaft, are of steel. The eccentric-strap and flywheel are cast iron, and the other portions of the engine are of brass. The screw threads are all chased, and the flange, *a*, and head of the piston, F, in addition to being screwed, are further secured by soft solder.

Fig. 1 shows the engine in perspective. Fig. 2 is a side elevation, with parts broken away. Fig. 3 is a vertical transverse section. Fig. 4 is a partial plan view. Fig. 5 is a detail view of the upper end of the connecting rod and its connections; and Fig. 6 is a horizontal section taken through the middle of the valve chamber.

The cylinder, A, is threaded externally for 1 inch from its lower end, and the collar, *a*, 1/4 inch thick, is screwed on and soldered. The face of the collar is afterward turned true. The same thread answers for the nut which clamps the cylinder in the plate, B, and for the gland, *b*, of the stuffing box, which screws over the beveled end of the cylinder, and contains fibrous packing filled with asbestos or graphite. The posts, C, are shouldered at the ends and secured in their places by nuts. Their bearing surface on the plate, D, is increased by the addition of a collar screwed on. The posts are made from drawn rods of brass, and need no turning except at the ends.

The cylinder head, E, which is a casting containing the valve chamber, is screwed in. The piston, F, fits the cylinder closely, but not necessarily steam tight. The head is screwed in and soldered, and the yoke, G, which receives the connecting rod pin, is screwed into the head. The connecting rod, H, is of steel, with brass ends. The lower end, which receives the crank pin, is split, and provided with a tangent screw for taking up wear. The crank pin is secured in the crank disk, I, by a nut on the back. The eccentric rod, J, is of steel, screwed at its lower end into an eccentric strap of cast or wrought iron, which surrounds the eccentric, K.

The valve, L, is slotted in the back to receive the valve spindle, by which it is oscillated. The ports are formed by drilling from the outside, and afterward forming the slot with a graver or small sharp chisel. The supply port, for convenience, may be somewhat enlarged below. The holes for the exhaust port will be drilled through the hole into which the exhaust pipe is screwed. The chamber communicating with the exhaust is cored out in the casting.

The easiest way to make the valve is to cut it out of a solid cylinder turned to fit the valve chamber.

An engine of this kind will work well under a steam pressure of 50 lb., and it may be run at the rate of 200 to 250 revolutions per minute.

It is desirable to construct a flat pasteboard model to verify measurements and to get the proper adjustment of the valve before beginning the engine. M.

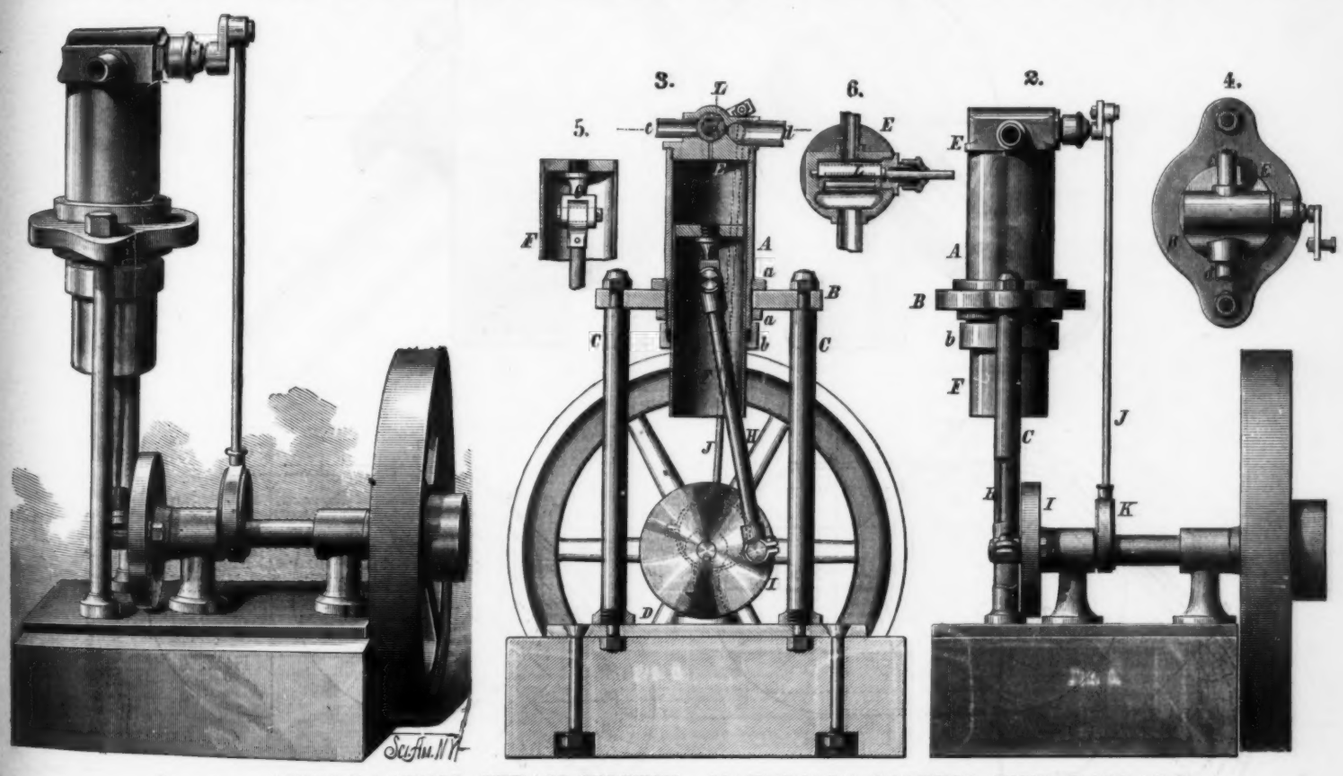


FIG. 1. SINGLE-ACTING STEAM ENGINE.—MATERIALS COSTING FIVE DOLLARS.

SEVERAL specimens of fossil woods and lignite have been found at a depth of one hundred and ninety-one feet below the surface in boring an artesian well at Galveston, Texas.

GOUBET'S SLEEVE COUPLING.

THE object of this sleeve is to transmit motion from one shaft to another which is inclined toward it in any direction whatever, and at any angle, provided it be not less than 90°. Fig. 1, next page, represents two shafts coupled together at this angle. The apparatus consists of two spheres, D, fixed near to each other at the ends of the shafts, immediately after the pillow blocks. Each of these is hollowed out, according to a plane passing through the axis of the shaft, into a groove or slot, in which are fitted collars that are connected with the shell, B, each through axles which are diametrically opposite.

If we suppose the shaft to the left to be in motion from left to right, it will be seen that the face of the groove cut in the sphere will rest against the anterior face of the collar to the left and carry along the latter in its motion communicated by the shell. The latter, in its turn, will carry along the collar to the right, whose face rests against the face of the groove in the sphere to the right, and communicate to it the impulsion with which it is being driven. The motion may be imparted indifferently by either the shaft to the left or the one to the right, and in one direction or the other. These collars moving in their grooves are the only portions of the mechanism liable to wear; they may, however, be easily lubricated by means of a grease box during their motion.

If we consider a point of contact between the face of the groove and the collar we shall remark that this point changes latitude, so to speak, on passing over circumferences of circles whose radii vary from one moment to another of motion. There results from this, then, a variation of velocity which is transmitted to the shell, and which would exist even were the latter the receiving shaft itself. But in consequence of the symmetrical position of the collars, due to the double system, the acceleration imparted by the transmitting shaft is corrected to an equal degree by a corresponding diminution in the velocity transmitted to the receiving shaft, and reciprocally; so that the latter revolves under the same conditions of speed as if it were the prolongation of the first shaft, and the more so since no transverse motion nor any lateral thrust against the bearings takes place. For a uniformity of the motion, it is indispensable that the angles formed by the axis of the sleeve and the axes of the shafts shall be equal.

The spaces passed over by the sleeve, corresponding with those passed over by the slot, may be determined in the following way: Take the slot in the position, O (Figs. 2 and 3), as a starting point, which at the same time will be that of the point, *m*, considered from the sleeve. Let *m n* be the space passed over by the point, *m*, in the slot during a quarter revolution of the sphere. Dividing this course into four equal parts and projecting on E F, we shall have the circles, 0′, 1′, 2′, 3′, 4′, corresponding to these divisions. Afterward, on dividing these circles into eight equal parts (Fig. 3), we shall obtain different positions of the slot to be

projected on Fig. 2. The points of intersection, 1, 2, 3, 4, of the slot in its different positions with the line, C D, that the point, *m*, must pass over, being projected on G H (Fig. 4), we shall obtain the spaces passed over by the *sleeve*, corresponding to those of the slot.

It may be remarked that during the first quarter revolution of the sphere, for equal spaces passed over by the slot, those passed over by the sleeve will go on increasing; and that during the second quarter (the slot always passing over equal spaces) those of the sleeve will go on decreasing. But, since the sleeve is provided at its other extremity with a like sphere, it follows that for unequal spaces passed over by the latter, those of the sphere will be equal, from whence it results that the transmitting and receiving shafts have velocities that are equal. In order to trace the curve obtained on the sphere, for a quarter revolution of the latter and of the sleeve, by means of a style placed at the point of intersection of any generatrix whatever, and a perpendicular to it, starting from the center of the sphere, the method of procedure is as follows:

Supposing a section of the sphere according to a plane passing through the line, A B, perpendicular to the axis, C D (Fig. 5). Fig 7 represents the space passed over by the style according to a plane perpendicular to the axis of the sleeve and passing through the center of the sphere. On this space, take a course equal to a quarter revolution of the sphere and divide it into four equal parts. Then project the points (Fig. 6), 0, I., II., III., IV., on the line, I J, and these points carried perpendicularly to the axis, C D, on the circumference, and then projected parallel to this axis on the line, K L (Fig. 5), will give the circles 0″, 1″, 2″, 3″, 4″, corresponding to the points of division of the style.

The points where the style and these circles meet, which will be so many points of the curve sought, are determined by projecting, parallel to the axis, C D, the points, I., II., III., IV., of the line, I J, on each corresponding circle of Fig. 5. Thus are obtained the points, 1, 2, 3, 4. These points, obtained solitarily, are carried back to the right of the axis, C D, by the following means: We divide the quarter sphere (Fig. 5) into a number of parts equal to those of the style's course; then, with spreads of compasses, equal to $1_1 1$, $2_2 2$, $3_3 3$, $4_4 4$ carried back to the right of the axis, C D, on the corresponding circles, we shall obtain the points, 0′, 1′, 2′, 3′, 4′, through which we must pass a curve, which will be the one sought, seen according to the plane passing through A B. On making these points on Fig. 6 we shall obtain the points, 0‴, 1‴, 2‴, 3‴, 4‴, which reunited will give the curve sought. For one entire revolution the style will generate on the sphere a curve like the Figure 8, which, in measure as the angle becomes greater, will go on diminishing in all directions until the two shafts are in a line with each other. At that instant the style will no longer be displaced.

In Fig. 1, A and A are the shaftings; B, the shell; C, the collars; D, the spheres, and E, the axles connecting the collars with the shell.

COMPRESSING AIR.*

By MR. JOHN STURGEON.

IN accordance with our promise on page 1064 of our issue of December 31 last, we give the following paper:

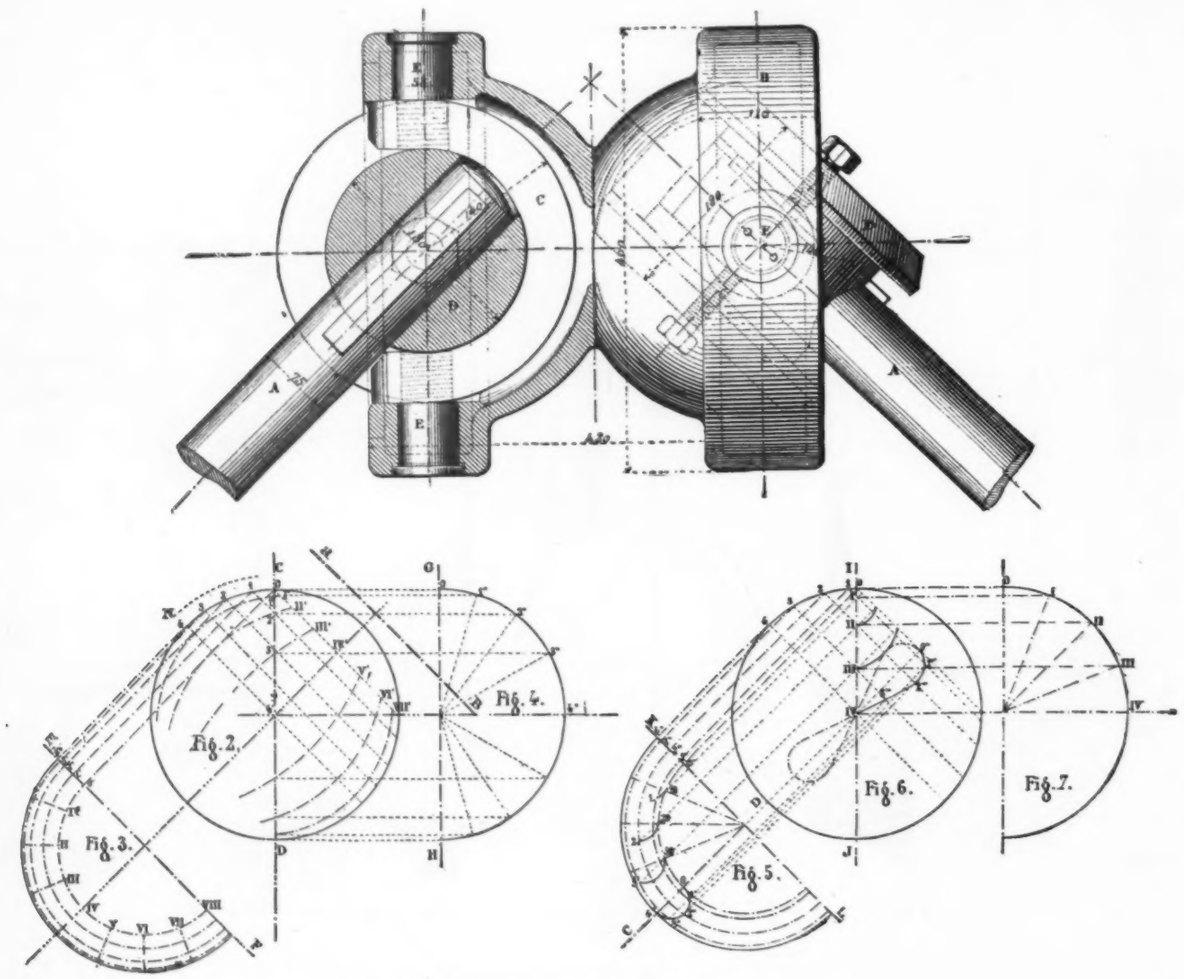
The subject of this paper, viz., "Compressing Air," embraces so wide a range that the writer cannot, in a paper like this, consider more than one branch of it. It has been so often discussed, in numerous papers and treatises, in its purely scientific aspect, that it is needless to go over again such well-trodden ground. It is proposed, therefore, that this paper shall be confined to examining into the most efficient and economical way of producing this most valuable motive power, leaving to some future occasion the consideration of its various applications. The gradual development of compressed air as a motive power—being entirely within the past twenty-five years—will be fresh in the memories of most of the members of this institute. Omitting, therefore, to sketch a history so modern and well known, the writer will proceed at once to give a brief description of each of the best known systems or types of air-compressing engines, pointing out what appear to him to be the failings of each. He will then examine briefly the conditions of the problem requiring solution, and how those conditions may be best dealt with and turned to advantage. He will then describe, with the aid of diagrams and illustrations, an air-compressing engine, designed and constructed as carefully as possible, in accordance with the conclusions to which the investigation leads.

The existing varieties of air-compressing engines may be divided into five distinct classes: 1. Direct-acting, without crank shaft or flywheel, after the style of a "special" pump; 2, "wet" compressors, in which the air is compressed by a column of water, caused to rise and fall in a vertical chamber by the movement of a piston in a horizontal cylinder communicating therewith; 3, flywheel compressors, of slow speed and long stroke; 4, flywheel compressors, of high speed and short stroke; 5, stage compressors, for very high pressure. Another class might be made of single-acting "trunk" compressors, as distinguished from ordinary double-acting piston compressors. There have also been a few eccentric varieties, such as rotary, semi-rotary, etc.; but as these have never come to anything, it would be needless to enlarge upon them.

The first of these classes—the direct-acting—may almost be considered obsolete. Indeed, it is difficult to conceive how compressors of this kind ever came into use, as they are in flat defiance of all the necessary conditions of compressing air. As members of this institute are well aware, in compressing air the load against the air piston is nothing at the commencement of the stroke, and gradually rises until it reaches its maximum toward the end of the stroke. In the direct-acting compressor there is no provision for storing up the power of the steam piston during the earlier part of the stroke when the load is at its minimum, to be given out when it reaches its maximum. The steam cylinder must be filled from end to end with steam of sufficient pressure to overcome the maximum load on the air piston when it reaches the end of its stroke. There is no possibility of using the steam expansively, and notwithstanding that the load varies so greatly, the steam power must be maintained without any variation whatever to the end of the stroke, and then allowed to rush out, without any expansion, producing a perfectly rectangular diagram. It is true the steam may be so throttled or wire drawn at the earlier part of the stroke as to have the appearance of being adapted equally to the load; but, as the terminal steam pressure must overpower the terminal air pressure, the cylinder must be filled with steam at the terminal pressure, and the result be an actual loss of power, owing to the throttling of the steam, although the steam expended will be the same as though used in full throughout the stroke. It may be imagined how wasteful of steam such engines must be. Again, as there is no crank action to define the limits of the stroke with unvarying accuracy, there must necessarily be a wide clearance and dead space at each end of the stroke, a clearance that varies very much in actual working, as there is no certainty about the length of stroke in these direct acting engines. Such engines are therefore only fit for very moderate pressures, and even then are most wasteful of steam. The writer has never known them capable of working at more than 35 to 40 lb. air pressure. There can be no doubt that the crank and flywheel are essential to make a good air compressor—the crank to regulate the limits of the piston travel from end to end of the stroke with accuracy, and the flywheel (as in all cases where an intermittent load or strain has to be overcome) to store up the power in the intervals when the load is least, in order to give it out again when the load reaches its greatest.

The second class, viz., "wet" compressors, are theoretically very perfect, as they insure a complete discharge of air from the cylinder at every stroke, leaving no dead spaces. But this advantage is more than counterbalanced by increased liability of formation of ice in the air driven engines, by loss of air by absorption in the water, and by the necessity of working the engines at such a very slow speed that the flywheel becomes rather a drag upon than an assistance to the action, sometimes even partially backing (as if to gather itself up for a fresh run) when it feels the resistance of the air cushion against the water column in the cylinder. It will readily be understood that an uncommonly long stroke with a very slow speed is unavoidable in these engines, to insure the steady rise and fall of the water. Any slight increase of speed sets the water in commotion; the piston may travel too fast for the descending column to follow it up closely (especially if the inlet valve area be small), so that a gap is left between the water and the piston, causing a shock and jar on the return of the piston. The water, dashed violently to and fro in the air chambers, causes rapid fluctuations of pressure throughout the stroke, producing a

* Read before the Chesterfield and Derbyshire Institute of Mining, Civil, and Mechanical Engineers, October 9, 1880.



GOUBET'S SLEEVE COUPLING.

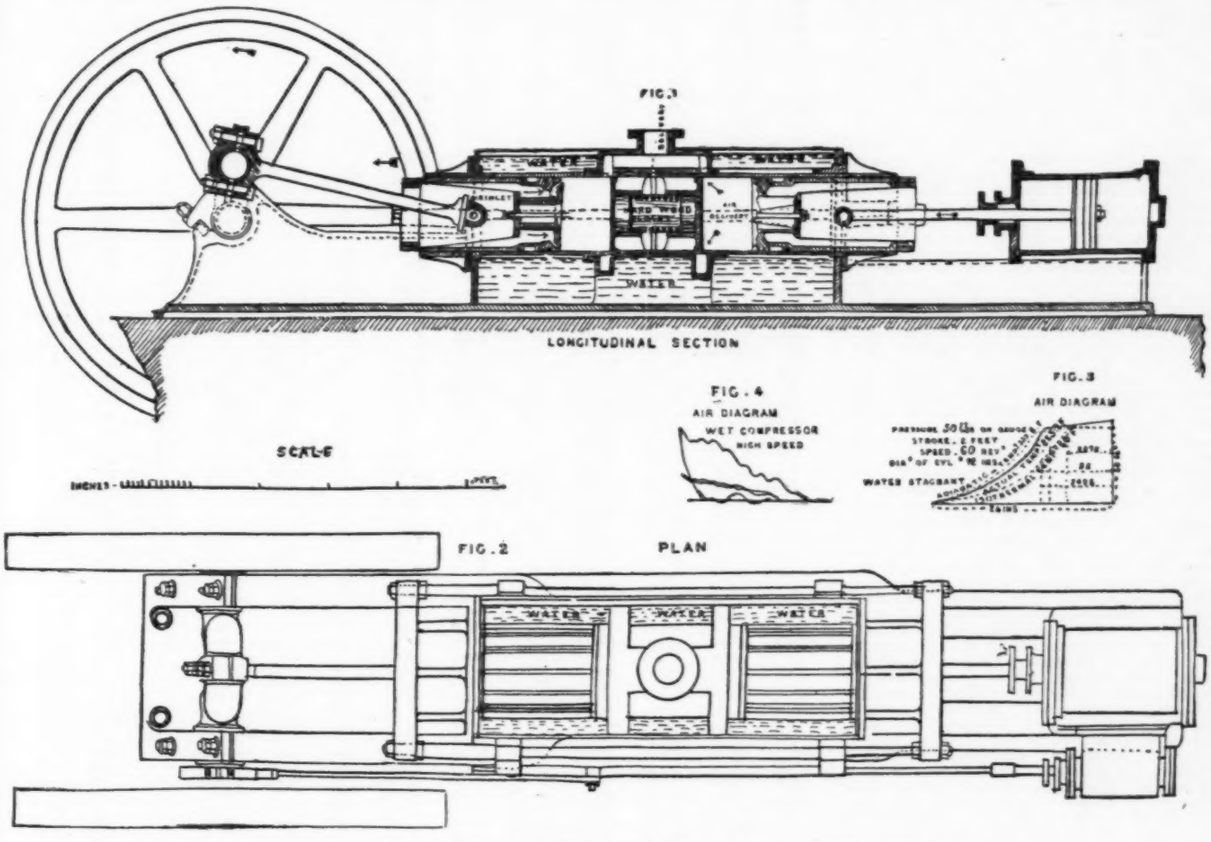
FIG. 1.—SECTION AND ELEVATION. FIGS. 2 TO 7.—TRACINGS OF THE CURVES OF MOTION.

diagram something like that shown in the plate, Fig. 4, which is drawn from memory from a diagram taken some years ago from a "wet" compressor—the original of which has been lost. In this case; being short of air, it was tried to get a little more by increasing the speed of the engine; but it was found that if the speed exceeded about eighteen to twenty revolutions per minute less air was got instead of more. Hence it requires a very large compressor on the wet principle to produce a comparatively small volume of compressed air. The stroke must be long, so as to have as few changes of direction as possible; the long stroke involves long guide bars, long crank, and connecting rod in proportion, and large flywheel, thus producing a most expensive machine for a small result, and necessitating very costly foundations; while the expenditure of power in overcoming the retarding forces of friction, inertia of the water, etc., is also very disproportionate to the useful effect. These last remarks apply equally to the third class, viz., dry compressors of long stroke and slow speed, with crank and flywheel. But there is a further disadvantage in these dry compressors, viz., that the slow speed allows time for a considerable amount of piston leakage to take place.

This brings the writer to one of the principal objects of this paper, namely, to call attention to the great advantages of the fourth class, that is, of high speeds with short strokes, over slow speeds with long strokes, in compressing air. When he first, about eleven years ago, began to advocate this system of high speeds and short strokes in compressing air, it met with much opposition and ridicule, which, though now beginning to die out, still crops up occasionally. For his part, he never could rightly understand how it came to be accepted as a sort of canon law that air could only be dealt with at slow speeds, but probably this notion may have arisen partly from the earlier air compressors being a modification of the blowing engine (like that erected at Govan Colliery in 1858), or on the wet principle, take place properly, and the cylinder could not take in as full a charge as at a slower speed. Hence the slow speed, which this defective valve arrangement alone rendered necessary, came to be regarded as an essential condition in compressing air. If, on the other hand, this notion of "pumping" be discarded, and the inlet valve be arranged, not to suit the conditions of pumping, but so as to compel its opening at the very beginning and hold it open all through the stroke, there will be no difficulty in filling the cylinder with air up to the atmospheric pressure, during the time of the stroke, at any speed at which an engine may be driven.

In the year 1875 a paper was read by Mr. Steel before the Society of Engineers, in London, in which he severely criticised the writer's notion of high speed, and gave several reasons for condemning that system, which are only referred to now, as the writer finds they are still the staple arguments of the advocates of slow speeds. As far as he could gather from the author of that paper and his disciples, the first reason given against high speed for compressing air was, that it was "barbarous;" the second, that it was wrong; the third, that slow speed must be right; the fourth, that nobody ever heard of such an absurd idea until a man of the name of Sturgeon brought it up; the fifth, that no air compressor yet made was found to work well at high speed; the sixth, that pumps for pumping water could not be worked at high speed; and, therefore, pumps for pumping air could not be worked at high speed; the seventh, that in course of time the machines would wear out.

With regard to the first four arguments of this series, the writer can only say that their "profound profundity of thought" completely shuts him up, and he gives up the task of combating them. He will only say that the logic, all through, is just about the same as is even still used by many people he comes across. The fifth is certainly correct in fact, as applied to the old-fashion slow compressors, though argument, it is, unfortunately, too true that machines do wear out, and that if we get more work out of them they will probably wear out somewhat faster than if we took less work out of them. Nevertheless, this fact does not appear to have sufficiently impressed locomotive engineers, millowners, and other users of large steam power, to induce them to abandon their bad ways. Neither is it allowed to interfere with quick running in underground hauling engines, rock drills, and other machines driven by compressed air. It is strange that of all classes of modern engines, this tenderness should be displayed only toward air-compressing engines, in which, owing to "circumstances over which they have no control," the advocates of slow speeds happen to find other causes operating to prevent high speeds, apart from the question of wear and tear. The writer must, however, refer to one objection which has been raised against high speed with better show of reason than any of the above, and that is this, that the heating must be very excessive. He thinks, however, he can show that this excessive heating is by no means a necessary accompaniment of high speed. The heat produced in compressing air arises from two causes—first, that due to compression—that is, the quantity of natural heat in a given volume of free air, when that air is compressed, is thus concentrated into a smaller compass, producing a rise in temperature. Such heat is unavoidable, and is due simply to the degree of compression without regard to speed. The second cause is friction—the friction of the particles of air against each other—and this will be proportionate to the speed with which the air is forced through the delivery valve passages. Now, in many of the slow speed compressors, the area of the outlet, when the delivery valve or valves are off their seats, is only about one-twentieth of the piston area, so that the velocity with which the air is driven through the delivery valve is twenty times the piston velocity. Now, if to the delivery valve be given double the area of outlet, making it one-tenth of the piston area, the



AIR COMPRESSOR FOR OBTAINING LOW PRESSURES.

or direct acting without flywheel; and partly from some confusion of ideas in the application of the term "pumping" to compressing air, through which the leading practice became committed to a certain system without much examination into the reasons on which it was based. Thus, in pursuance of this notion of "pumping" air, the inlet valves were made just like pump clack valves, depending on a vacuum or suction for opening to admit the air, and this arrangement in itself necessitated slow speeds; not that there was any special or physical difficulty in getting the air to enter a cylinder at high speed, but solely owing to the mechanical defects and total unsuitableness of valves of the pump-clack form as applied to air. This will at once be seen from an examination into their action. At the end of the stroke of the air piston a certain quantity of undischarged compressed air is left in the clearance and dead spaces in the cylinder. This undischarged air expands back into the cylinder as the piston recedes until it reaches atmospheric pressure. The further movement of the piston then begins to produce a partial vacuum in the cylinder, and this goes on increasing until the vacuum is sufficient to overcome the weight of the valve, plus its inertia, and lift it off its seat. A puff of air then enters the cylinder, which immediately restores equilibrium, causing the valve to be shut down again upon its seat. The continued travel of the piston again produces a partial vacuum, overcomes first the weight, and then the inertia of the valve, and lets in another puff of air; and so on, repeating the same action throughout the stroke, and producing that rattle with which we are familiar. The cylinder will, therefore, never fill with air at the atmospheric pressure, but will always, even when at its best, be minus to an extent corresponding to the weight and inertia of the valve. Now it is evident that a rapid travel of the piston would not allow time for the operations above described to quite wrong in the inference—for it by no means follows that merely because a thing has not been done in the past, it could not be done in the future. The sixth is a most extraordinary reason, when the utter absence of any analogy between the two operations—pumping water and compressing air—is considered. Water is a heavy, incompressible fluid, without any elasticity, possessing a great amount of inertia, and of momentum when set in motion; presenting a uniform resistance against the piston throughout its stroke, and a skin resistance in the cylinder, pipes, etc., about 1,336 times greater than that of air; and these are sufficient reasons for rendering slow speed advisable for pumping water. Air, on the other hand, possesses properties as completely the opposite of these as it is possible to conceive. It is a fluid, the particles of which mutually repel each other—that is to say, it is a "gas," highly elastic and light; the skin resistance comparatively infinitesimal, offering a resistance against the piston gradually increasing from nothing upward, subject, in fact, to all the laws that govern gaseous bodies, as compressibility, expansibility, change of volume, pressure, temperature, etc., and in all these respects the same as steam. And yet we are told we are not to deal with it as we would with steam, which it resembles in all these properties, but that we must deal with it as we would with water, which it does not resemble in one single property! Not a single one of the causes which render slow piston speed advisable in pumping water exists in the case of air; and with a proper construction of valves suitable for the character of the work to be done—and not a mere servile imitation of pumps—there is no reason, in the nature of things, why a piston compresing air should not be run at as high a speed as the piston of any steam engine; or why the piston compressing the air should not be run at as high a speed as we would not hesitate to put the same piston to when driven by the compressed air. As regards the seventh piston speed can at once be doubled without increasing the velocity of the air through the valve passages, and, consequently, without increasing the frictional heat. This is really what, in the writer's engines, is done. He gives the delivery valves all the area he can possibly get in, and, if it were possible, would give them the full area of the cylinder. He has just received from a friend the following particulars in reference to his air compressors, which fully confirm all that is here advanced:

"Size of air compressing cylinders, 18 in. diameter by 4 ft. stroke; valves originally on air cylinders, seven suction and seven delivery valves at each end of cylinders; valves 1¼ in. diameter, with three wings on each valve ¼ in. thick; lift of valves ⅝ in., giving total passage area of 14 square inches nearly. Temperature of water running through one and one-half inch pipe into cooling tanks, 48°; temperature of water in tanks, with engine running forty strokes per minute, 130° to 180°. Valves on air cylinders, as lately altered, fifteen suction and fifteen delivery valves at each end, same size and lift as before, giving total passage area of 30 in. nearly. Temperature of water running through two inch pipe into cooling tank, 48°; temperature of water in tanks, with engine running forty-six strokes per minute, 75°. Pressure of air, 50 lb. per square inch, and water continually running in both cases."

The writer hopes he has succeeded in showing that there are no valid reasons or obstacles against high speed in compressing air; and, such being the case, will now endeavor to show what important reasons there are in favor thereof. The first and most obvious advantage is economy in first cost, not only in the engine itself, but to a far greater extent in the foundations, engine house, and other accessories. For example, it is not uncommon to find air compressors of proportions something like the following, viz.: Air cylinder, 24 in. diameter, with stroke of 6 ft.; a

flywheel, 24 ft. diameter, and a length over all of nearly 60 ft.; maximum effective speed, about twenty revolutions per minute. An equal volume of air can be obtained in the same time, with a less expenditure of power, from a "trunk" air compressor of 17 in. diameter, about 30 inches stroke, having a flywheel 10 ft. diameter, and a length over all of about 28 ft., and running at a speed of about ninety revolutions per minute. Therefore, in the matter of size alone, there is ample justification for resorting to high speeds, allowing that there is no physical obstacle in the way, as it has been endeavored to show. Indeed, but for having been drawn into the slow speed system, by an accidental run of circumstances, the writer believes the high speed principle would have been adopted as the natural and proper one without any question or doubt.

Another advantage in high speed is that it reduces the amount of piston leakage. In air compressors of the ordinary types this piston leakage is often considerable. The longer the piston is exposed to the air pressure the greater is the loss by leakage, as it is going on during the whole time, to a greater or less degree, according to the perfection or otherwise of the fit of the piston, but always to some extent even with the most perfect fit. This leakage entails a double loss. First, there is the direct loss in the volume actually compressed, by so much being abstracted from it; and secondly, there is an indirect loss, but one of even more mischievous extent, arising from the fact that the air so leaking past the piston is hot air, and that it passes direct to the entering side of the cylinder, mingling with the entering air, warming it, and thereby increasing its tension, so as to prevent the cylinder receiving a full charge of air at the atmospheric temperature and pressure, and thus adding another to the causes already mentioned as preventing the entrapment of a full body of atmospheric air into the cylinder for compression. This forms a very serious, and, probably, not generally suspected, source of loss in compressing air; and it is further increased by reason of the hot compressed air that was left behind in the dead spaces also mixing with the new incoming air. It is a loss not easily traced in ordinary compressors, as it would not be exhibited in any distinct form in an indicator diagram. Indeed, a very fair diagram, so far as appearance goes, might be produced, showing such a near approach of the actual compression line to the isothermal line as to appear at first sight to be due to a most efficient cooling action, keeping down the rise of temperature in compressing, while in reality it may, and in most cases does, signify nothing less than that the compression line is reduced by piston slip or leakage, not by reduction of temperature. Now, as the amount of this leakage depends not only on the degree of pressure, but on the time to which the piston is exposed to that pressure, the importance of reducing that time as much as possible becomes at once apparent. Therefore, the quicker the piston is in traversing the cylinder, and the sooner the charge of air is sent out of it and trapped behind the delivery valve, the less of that charge will be lost, and the less will be the next incoming charge of atmospheric air be interfered with. This is a most important advantage which the quick speed with short stroke has over the slow speed with long stroke.

The writer will now proceed to point out what he considers to be the essential conditions in the design and construction of an air compressor in order to attain the highest degree of efficiency:

First, the piston should be a good sliding fit, and present the greatest possible resistance to leakage. Second, the leakage, whatever it might be, should not be allowed to pass to the entering side so as to mix with the incoming air, but should pass out harmlessly into the free atmosphere. Third, the stroke should be short and quick, to allow as little chance as possible for leakage. Fourth, there should be no clearance or dead spaces whatever, in which compressed air might be left in the cylinder at the end of the piston travel, but each stroke of the piston should sweep the cylinder entirely clear of its charge of air. Fifth, and yet the construction should be such as to prevent danger of knocking out the cylinder end. Sixth, the inlet valve should be of large area, and should open at the very commencement of the back stroke of the piston, and remain wide open all through the stroke; and it should shut immediately before or simultaneously with the commencement of the forward stroke, so as to lose nothing of the stroke in compressing. Seventh, the delivery valve should have as large an area as possible, with short lift, so as to return quickly to its seat; it should open in the direction of the movement of the piston, to render the exit of the air as easy as possible, and reduce the liability to frictional heating. Eighth, every possible means should be adopted to reduce the heat of compression and friction, by means of an efficient water circulation applied both to the outside and the inside of the air cylinder. Ninth, and yet the water should be kept from direct contact and admixture with the air, so as to avoid the great disadvantage of having to work with wet air, as well as the actual loss in volume by absorption in the water. Tenth, the momentum of the piston should increase as the pressure of air rises against it. Eleventh, every part should be easily accessible for examination and repairs. Twelfth, the general construction should be as simple and free from complication as possible, and possess great strength and solidity.

With regard to the ninth point, the writer would observe that the practice of injecting water into the compressing cylinder is objectionable from a practical point of view, in consequence of the danger it introduces of breaking the joint of the cylinder cover, as arranged in air cylinders of ordinary construction. In a steam cylinder it is admitted that we cannot be too careful in keeping it free from condensed water; and yet in air cylinders water is often actually injected, introducing the very element of danger we are so careful to exclude in steam cylinders. If, however, the entire end of the cylinder were so arranged as to yield to the pressure, water might be injected without risk or danger. Another objection to the injection of water is that the air becomes saturated with moisture, which is liable to form ice or snow in the exhaust ports of the driven engine. Indeed, there is quite enough inconvenience from this cause acising from the natural moisture contained in the atmosphere, without increasing it by artificial means. By compression, the capacity of the air for retaining its moisture is diminished (just as in the case of a sponge), and the moisture is discharged in the form of visible cloud or fog. In this condition, and while still under pressure, it may be condensed and collected by means of baffle plates, traps, or porous absorbing substances before reaching the driven engine. By carefully avoiding the injection of water, and by thus abstracting the natural moisture, the formation of ice by the cold expanding air is prevented. The patent "trunk" compressor, of which Figs. 1 and 2 give a longitudinal section and plan, the writer believes, fulfills all the above conditions in as complete a manner as possible. It consists of two horizontal single-acting air cylinders, opposite one another, and fitted with trunk pistons connected together by two side rods passing outside the cylinders, and connected to crossheads at the outer ends of the pistons, thus forming a double-acting machine, with the cylinders entirely open on the air inlet sides, and with the connecting rods coupled direct from the crank to the nearest piston, without the intervention of crosshead and parallel slide bars By this arrangement are obtained all the advantages of a deep piston in its resistance to leakage of the air without adding materially to the length of the machine, the extra cylinder and piston occupying the place of the parallel slide bars in the closed cylinder arrangement. The ends of the cylinder being open, any leakage of air past the trunk piston is at once discernible, and the trunks can be taken out, set right, and replaced without breaking any joint. Any such leakage as might take place passes harmlessly out into the free air, and does not mix with the incoming air. The inlet valves are open to inspection, and the pistons and cylinders can be cleaned and lubricated without disturbing any part of the machine,

TABLE OF PRESSURES, TEMPERATURES, VOLUMES, RATIO OF VOLUMES, MEAN PRESSURES, &c., OF COMPRESSED AIR AND PERMANENT GASES.

PREPARED BY ISAAC SHONE, C.E., F.G.S., WREXHAM, 1880.

Absolute Pressure in lbs. per square inch.	Temperature (Fah. deg.) above:		Temperature (Cent. deg.) above:		Volumes of Compressed Air or Gas. With Temperature:		Pressures above Atmosphere:—Col. A—14·7 lbs.	Ratio of Volume at Atmospheric Pressure to Volumes at Pressures in Cols. A and H With Temperature:		Point of Stroke at which Pressures would be reached when Stroke = 1, and Compressors take in Air at Normal Temp. and Press. With Temperature:		Mean or Average Load throughout the Stroke against Compressing Piston, in lbs. per square inch above atmosphere. With Temperature:	
	Absolute Zero.	Fah. Zero.	Absolute Zero.	Cent. Zero.	Variable.	Constant.		Variable. 100 / Col. F.	Constant. 100 / Col. G.	Variable.	Constant.	Variable.	Constant.
A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.	N.	O.
0	0	—461·20	0	—274·00	Infinite.	Infinite.	—14·7						
1	+239·05	—222·15	+132·81	—141·19	674·21	1470·00	—13·7						
2	292·27	—168·93	162·36	—111·64	412·16	735·00	—12·7						
3	328·74	—132·47	182·63	— 91·37	309·06	490·00	—11·7						
4	357·34	—103·86	198·52	— 75·48	251·96	367·50	—10·7						
5	381·23	— 79·98	211·79	— 62·21	215·04	294·00	— 9·7						
6	401·93	— 59·27	223·29	— 50·71	188·93	245·00	— 8·7						
7	420·30	— 40·90	233·50	— 40·50	169·35	210·00	— 7·7						
8	436·90	— 24·65	242·72	— 31·28	154·03	183·75	— 6·7						
9	452·08	— 9·12	251·16	— 22·84	141·67	163·333	— 5·7						
10	466·10	+ 4·90	258·94	— 15·06	131·46	147·00	— 4·7						
11	479·17	18·06	266·21	— 7·79	122·86	133·636	— 3·7						
12	491·41	30·21	273·02	— 0·98	115·50	122·50	— 2·7						
13	502·95	41·75	279·41	+ 5·41	109·12	113·077	— 1·7						
14	513·88	52·69	285·49	11·49	103·53	105·00	— 0·7						
14·7	521·20	60·00	289·56	15·56	100·00	100·00	0·0						
15·7	531·24	70·04	295·13	21·13	95·435	93·631	1	1·0478	1·0680	·954	·936	0·978	·947
16·7	540·84	79·64	300·47	26·47	91·341	88·024	2	1·0948	1·1361	·913	·880	1·937	1·874
17·7	550·04	88·84	305·58	31·58	87·646	83·051	3	1·1409	1·2041	·876	·831	2·846	2·680
18·7	558·88	97·68	310·49	36·49	84·292	78·610	4	1·1864	1·2721	·843	·786	3·805	3·513
19·7	567·38	106·18	315·21	41·21	81·231	74·619	5	1·2310	1·3401	·812	·746	4·615	4·308
20·7	575·59	114·39	319·77	45·77	78·443	71·031	6	1·2748	1·4078	·784	·710	5·419	5·055
21·7	583·52	122·32	324·18	50·18	75·842	67·742	7	1·3185	1·4762	·758	·677	6·326	5·762
22·7	591·19	129·99	328·44	54·44	73·454	64·758	8	1·3614	1·5442	·735	·648	7·101	6·347
23·7	598·63	137·43	332·57	58·57	71·240	62·025	9	1·4037	1·6122	·712	·620	7·865	7·000
24·7	605·85	144·65	336·58	62·58	69·180	59·514	10	1·4455	1·6803	·692	·595	8·737	7·626
25·7	612·86	151·66	340·48	66·48	67·258	57·198	11	1·4868	1·7483	·673	·572	9·479	8·235
26·7	619·68	158·48	344·27	70·27	65·459	55·056	12	1·5277	1·8164	·655	·551	10·211	8·803
27·7	626·33	165·13	347·96	73·96	63·773	53·069	13	1·5681	1·8844	·638	·531	10·934	9·290
28·7	632·80	171·60	351·56	77·56	62·187	51·220	14	1·6081	1·9524	·622	·512	11·647	9·817
29·7	639·12	177·92	355·07	81·07	60·693	49·495	15	1·6476	2·0204	·607	·495	12·353	10·326
30·7	645·29	184·09	358·49	84·49	59·283	47·883	16	1·6868	2·0884	·593	·479	13·049	10·837
31·7	651·31	190·11	361·84	87·84	57·949	46·372	17	1·7257	2·1565	·579	·464	13·738	11·330
32·7	657·21	196·01	365·12	91·12	56·685	44·954	18	1·7641	2·2245	·567	·450	14·414	11·723
33·7	662·97	201·77	368·32	94·32	55·485	43·630	19	1·8023	2·2925	·555	·436	14·990	12·180
34·7	668·62	207·42	371·46	97·46	54·345	42·363	20	1·8401	2·3605	·543	·424	15·657	12·623
35·7	674·15	212·95	374·53	100·53	53·260	41·176	21	1·8776	2·4286	·533	·412	16·317	13·052
36·7	679·57	218·37	377·54	103·54	52·225	40·054	22	1·9148	2·4966	·522	·401	16·870	13·470
37·7	684·89	223·69	380·49	106·49	51·238	38·992	23	1·9517	2·5646	·512	·390	17·516	13·818
38·7	690·11	228·91	383·39	109·39	50·295	37·984	24	1·9883	2·6327	·503	·380	18·157	14·215
39·7	695·23	234·03	386·24	112·24	49·392	37·028	25	2·0246	2·7007	·494	·370	18·695	14·602
40·7	700·27	239·07	389·04	115·04	48·527	36·118	26	2·0607	2·7687	·485	·361	19·324	14·976
41·7	705·22	244·02	391·79	117·79	47·698	35·252	27	2·0965	2·8367	·477	·353	19·946	15·344
42·7	710·08	248·88	394·49	120·49	46·902	34·426	28	2·1321	2·9048	·469	·344	20·470	15·651
43·7	714·86	253·66	397·15	123·15	46·136	33·638	29	2·1675	2·9728	·461	·336	21·081	16·002
44·7	719·57	258·37	399·76	125·76	45·402	32·886	30	2·2025	3·0408	·454	·329	21·597	16·345
45·7	724·20	263·00	402·33	128·33	44·695	32·166	31	2·2374	3·1088	·447	·322	22·199	16·679
46·7	728·76	267·56	404·87	130·87	44·013	31·478	32	2·2721	3·1769	·440	·315	22·704	17·006
47·7	733·25	272·05	407·36	133·36	43·356	30·818	33	2·3065	3·2449	·434	·308	23·295	17·281
48·7	737·68	276·48	409·82	135·82	42·722	30·185	34	2·3407	3·3129	·427	·302	23·794	17·594
49·7	742·04	280·84	412·24	138·24	42·110	29·577	35	2·3747	3·3810	·421	·296	24·288	17·903
50·7	746·34	285·14	414·63	140·63	41·518	28·994	36	2·4086	3·4490	·415	·290	24·865	18·204
51·7	750·58	289·38	416·99	142·99	40·947	28·433	37	2·4422	3·5170	·409	·284	25·353	18·500
52·7	754·76	293·56	419·32	145·32	40·393	27·894	38	2·4757	3·5850	·404	·279	25·923	18·790
53·7	758·88	297·68	421·60	147·60	39·858	27·374	39	2·5089	3·6531	·399	·274	26·402	19·032
54·7	762·95	301·75	423·86	149·86	39·339	26·874	40	2·5420	3·7211	·393	·269	26·878	19·311
55·7	766·97	305·77	426·09	152·09	38·836	26·391	41	2·5749	3·7891	·388	·264	27·350	19·586
56·7	770·94	309·74	428·30	154·30	38·349	25·926	42	2·6076	3·8571	·383	·259	27·905	19·855
57·7	774·86	313·66	430·48	156·48	37·876	25·477	43	2·6403	3·9252	·379	·255	28·370	20·118
58·7	778·73	317·53	432·63	158·63	37·416	25·043	44	2·6726	3·9932	·374	·250	28·834	20·342
59·7	782·56	321·36	434·76	160·76	36·970	24·623	45	2·7049	4·0612	·370	·246	29·295	20·598
60·7	786·33	325·13	436·85	162·85	36·537	24·217	46	2·7370	4·1293	·365	·242	29·833	20·840
61·7	790·07	328·87	438·93	164·93	36·115	23·825	47	2·7689	4·1973	·361	·238	30·285	21·096
62·7	793·76	332·56	440·98	166·98	35·706	23·445	48	2·8007	4·2653	·357	·234	30·737	21·330
63·7	797·41	336·21	443·01	169·01	35·307	23·077	49	2·8323	4·3333	·353	·231	31·187	21·544
64·7	801·02	339·82	445·01	171·01	34·918	22·720	50	2·8638	4·4014	·349	·227	31·632	21·780
65·7	804·59	343·39	446·99	172·99	34·540	22·374	51	2·8952	4·4694	·345	·224	32·154	22·012
66·7	808·13	346·93	448·96	174·96	34·172	22·039	52	2·9264	4·5374	·342	·220	32·594	22·040
67·7	811·62	350·42	450·90	176·90	33·813	21·713	53	2·9575	4·6054	·338	·217	33·033	22·465
68·7	815·08	353·88	452·82	178·82	33·462	21·397	54	2·9884	4·6735	·335	·214	33·468	22·656
69·7	818·50	357·30	454·72	180·72	33·121	21·090	55	3·0193	4·7415	·331	·211	33·901	22·873
70·7	821·89	360·69	456·61	182·61	32·787	20·792	56	3·0499	4·8095	·328	·208	34·330	23·089
71·7	825·25	364·05	458·47	184·47	32·462	20·502	57	3·0805	4·8776	·325	·205	34·758	23·301
72·7	828·57	367·37	460·32	186·32	32·144	20·220	58	3·1110	4·9456	·321	·202	35·183	23·511
73·7	831·86	370·66	462·14	188·14	31·834	19·946	59	3·1413	5·0136	·318	·199	35·607	23·688
74·7	835·11	373·91	463·95	189·95	31·531	19·679	60	3·1715	5·0816	·315	·197	36·027	23·892
75·7	838·34	377·14	465·74	191·74	31·235	19·419	61	3·2016	5·1497	·312	·194	36·448	24·092
76·7	841·54	380·34	467·52	193·52	30·945	19·166	62	3·2315	5·2177	·309	·192	36·864	24·292
77·7	844·70	383·50	469·28	195·28	30·662	18·919	63	3·2614	5·2857	·307	·189	37·277	24·497
78·7	847·84	386·64	471·02	197·02	30·385	18·679	64	3·2911	5·3537	·304	·187	37·690	24·653
79·7	850·95	389·75	472·75	198·75	30·113	18·444	65	3·3208	5·4218	·301	·184	38·098	24·844
80·7	854·04	392·84	474·47	200·47	29·848	18·216	66	3·3503	5·4898	·298	·182	38·509	25·033
81·7	857·09	395·89	476·16	202·16	29·588	17·993	67	3·3797	5·5578	·296	·180	38·914	25·219
82·7	860·12	398·92	477·84	203·84	29·334	17·775	68	3·4091	5·6259	·293	·178	39·317	25·403
83·7	863·12	401·92	479·51	205·51	29·084	17·563	69	3·4383	5·6939	·291	·176	39·720	25·559
84·7	866·10	404·90	481·17	207·17	28·840	17·355	70	3·4674	5·7619	·288	·174	40·121	25·738
85·7	869·05	407·85	482·81	208·81	28·601	17·153	71	3·4964	5·8299	·286	·172	40·518	25·915
86·7	871·98	410·78	484·43	210·43	28·366	16·955	72	3·5253	5·8980	·284	·170	40·913	26·093
87·7	874·89	413·69	486·05	212·05	28·136	16·762	73	3·5541	5·9660	·281	·168	41·237	26·264
88·7	877·77	416·57	487·65	213·65	27·911	16·573	74	3·5829	6·0340	·279	·166	41·631	26·411
89·7	880·63	419·43	489·24	215·24	27·689	16·388	75	3·6115	6·1020	·277	·164	42·021	26·583
90·7	883·46	422·26	490·81	216·81	27·472	16·207	76	3·6400	6·1701	·275	·162	42·411	26·750
91·7	886·28	425·08	492·38	218·38	27·259	16·031	77	3·6685	6·2381	·273	·160	42·797	26·916
92·7	889·07	427·87	493·93	219·93	27·050	15·858	78	3·6969	6·3061	·271	·159	43·182	27·079
93·7	891·84	430·64	495·47	221·47	26·845	15·688	79	3·7251	6·3742	·268	·157	43·566	27·218
94·7	894·59	433·39	496·99	222·99	26·643	15·521	80	3·7533	6·4422	·266	·155	43·882	27·379
95·7	897·32	436·12	498·51	224·51	26·445	15·361	81	3·7814	6·5102	·264	·154	44·260	27·538
96·7	900·03	438·83	500·02	226·02	26·251	15·202	82	3·8094	6·5782	·263	·152	44·639	27·695
97·7	902·72	441·52	501·51	227·51	26·060	15·046	83	3·8373	6·6463	·261	·150	45·017	27·851
98·7	905·39	444·19	502·99	228·99	25·872	14·894	84	3·8652	6·7143	·259	·149	45·393	27·983
99·7	908·04	446·84	504·47	230·47	25·687	14·744	85	3·8929	6·7823	·257	·147	45·700	28·136
100·7	910·67	449·47	505·93	231·93	25·506	14·598	86	3·9260	6·8503	·255	·146	46·137	28·286
101·7	913·28	452·08	507·38	233·38	25·328	14·454	87	3·9482	6·9184	·253	·145	46·443	28·436
102·7	915·88	454·68	508·82	234·82	25·153	14·314	88	3·9757	6·9864	·252	·143	46·813	28·584
103·7	918·46	457·26	510·26	236·26	24·980	14·176	89	4·0032	7·0544	·250	·142	47·115	28·709
104·7	921·02	459·82	511·68	237·68	24·753	14·040	90	4·0306	7·1224	·248	·140	47·482	28·855
105·7	923·56	462·36	513·09	239·09	24·643	13·907	91	4·0579	7·1905	·246	·139	47·847	25·999
106·7	926·08	464·88	514·49	240·49	24·479	13·777	92	4·0851	7·2585	·245	·138	48·209	29·141
107·7	928·59	467·39	515·88	241·88	24·318	13·649	93	4·1122	7·3265	·243	·136	48·507	29·282
108·7	931·08	469·88	517·27	243·27	24·159	13·523	94	4·1393	7·3946	·242	·135	48·869	29·401
109·7	933·56	472·36	518·64	244·64	24·002	13·400	95	4·1663	7·4626	·240	·134	49·227	29·541
110·7	936·02	474·82	520·01	246·01	23·848	13·279	96	4·1933	7·5306	·238	·133	49·522	29·678
111·7	938·46	477·26	521·37	247·37	23·696	13·160	97	4·2201	7·5986	·237	·132	49·878	29·813
112·7	940·89	479·69	522·72	248·72	23·547	13·044	98	4·2469	7·6667	·235	·130	50·234	29·948
113·7	943·31	482·11	524·06	250·06	23·399	12·929	99	4·2736	7·7347	·234	·129	50·525	30·063
114·7	945·71	484·51	525·39	251·39	23·254	12·816	100	4·3003	7·8027	·233	·128	50·878	30·195

and, being freely open to the atmosphere, are more easily kept cool. The parts in which the pistons work are made of special metal, cast as thin as possible, and ribbed lengthways, so as to facilitate the conducting power by increasing the surface and keeping the metal thin, at the same time that the ribs serve to strengthen it. Water circulation is arranged to pass outside the cylinder, as well as through a recess formed in the forepart of the trunk, by which the cylinder is cooled and lubricated internally by the water, as well as externally without allowing the water to mix directly with the air. The trunk pistons and interior of the cylinder, being always open to inspection, can be easily kept in the most perfect working order. Owing to the weight of the trunk piston, its momentum increases toward the end of the stroke, where the resistance of the air compressed in the cylinder is increasing against it, thus greatly assisting in the work of compressing the air. At the same time the great extent of bearing surface removes any objection as to the wear, there being in reality very much less weight upon each square inch of bearing surface than in the case of the ordinary narrow piston. The inlet valves are placed one in the head of each piston, and so arranged as to open and close instantaneously by the action of their own momentum, on the reversal of the piston, independently of the formation of a vacuum or pressure in the cylinder, and as they travel with the piston, against the air when open, and also when closed, they necessarily retain their proper position throughout the whole of both backward and forward strokes. The delivery valves open direct into an air-receiving chamber in the middle, between the two working cylinders. Each delivery valve consists of a flat disk covering the whole bore of the cylinder, and so arranged that the piston may run close up to it, thus discharging the whole of the air from the cylinder, the clearance being, in fact, behind the valve instead of inside the cylinder. Thus all the danger of breakage in the case of narrow clearance and a fixed cylinder end is avoided. The delivery valve area may also be further increased, by covering the whole area of the disk with any convenient number of small delivery valves, working within the main disk valve.

With these compressors the writer never found any difficulty in raising the pressure up to 200 lb. in a single stage of compression; and, so far as he can see, there would be no difficulty in obtaining very much higher pressures, such as have hitherto been only attempted in stages, by making the cylinders of sufficient strength to withstand the pressure, and applying steam cylinders of sufficient power, and with a good leverage of the crank of the steam cylinder over the crank of the compressing cylinder. The question of stage compressing, however, belongs rather to that of the applications of compressed air, which he hopes to bring before the institute at some future time, when, perhaps, he may have been able to make some experiments in that direction. Fig. 3 is a diagram taken from a trunk compressor with cylinders of 12 in. diameter and 2 ft. stroke, after the engine had been running for about an hour. As the trial was made in the workshop immediately after the engine was completed, and there was no convenience for maintaining a continuous water circulation, the water was stagnant in the casing the whole time. It therefore shows a higher degree of heat than there should be, indicating a rise of temperature from 60° to 273·7° Fah. With an efficient water circulation this would be very greatly reduced. The leakage was imperceptible, not being sufficient to deflect a flame applied close to the outer edge of the cylinder.

Another important question in connection with air compressing is that of the percentage of useful effect realized. But as this paper is already sufficiently long, the writer must leave the consideration of that part of the subject to be dealt with under the head of the application of compressed air power, to which it more properly belongs, as so much of the efficiency of the system depends upon the mode of application, after we have done all in our power to attain the highest efficiency and economy in the production of the compressed air. It is, indeed, impossible to apply any fixed rule, as the results will vary with every pound variation of pressure, with the mode of application, and even with the state of the weather, the same machine producing different results on a dry and crisp day to what it does on a wet or foggy day. The results are, therefore, very variable and often contradictory.

On the preceding page is a set of tables, compiled by Mr. Isaac Shone, C.E., of Wrexham, the inventor of Shone's pneumatic sewerage system, and the patent pneumatic liquid ejector. These tables are carefully revised and largely extended from Professor Thurston's well-known tables, having six additional and entirely original columns, showing the ratio of volume to pressure, the points of the stroke at which the stated pressures are reached, and the average pressures upon the piston, both with temperature variable and constant. They will be found of great practical use by all who have to do with compressed air in facilitating calculations.

FORMULÆ.

Let t = total absolute temp. due to the degree of tension of the air, the normal press. and temp. being taken at 14·7 lb. per sq. in. and 60° F. respectively.
T = normal temp. — 60° F., or 15·56° C.
p = ultimate press. of air given in Col. A.
P = normal press. of air = 14·7 lb. per sq. in.
R = ratio of compression.
H = hyperbolic log. of R.

$$\left.\begin{array}{l}\text{Then Col. B} = t = \left(\frac{p}{P}\right)^{0\cdot29} \times (461\cdot2 + T) \\ \text{Col. C} = (\text{Col. B} - 461\cdot2) = t - 461\cdot2\end{array}\right\} \text{Fah. degrees.}$$

$$\left.\begin{array}{l}\text{Col. D} = t = \left(\frac{p}{P}\right)^{0\cdot29} + (274 + T \\ \text{Col. G} = t - 274 = \text{Col. D} - 274\end{array}\right\} \text{Cent. degrees.}$$

$$\text{Col. F} = \text{Col. G} \times \frac{461\cdot2 + t}{461\cdot2 + T} = \text{Col. G} \times \frac{461\cdot2 + \text{Col. B}}{461\cdot2 + 60}$$

$$\text{Col. G} = \frac{P \times 100}{p} = \frac{14\cdot7 \times 100}{\text{Col. A}}$$

$$\text{Col. H} = \text{Col. A.} - 14\cdot7 = p - P.$$

$$\text{Col. I} = 100 \div \text{Col. F.}$$

$$\text{Col. K} = 100 \div \text{Col. G.}$$

$$\text{Col. L} = 1 \div \text{Col. I.}$$

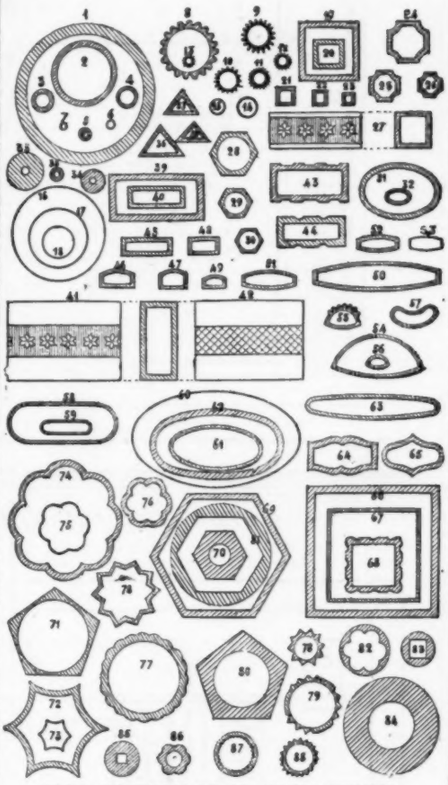
$$\text{Col. M} = 1 \div \text{Col. K.}$$

$$\text{Col. N} = p \times \frac{1 + H}{R} - P;\ R\ \frac{c}{c1};\ c1 = \frac{c \times t}{T};\ c = 100$$

$$\text{Col. O} = p \times \frac{1 + H}{R} - P;\ R = \frac{p}{P}$$

SEAMLESS TUBING.

MESSRS. DURAND, BOSSIN & BRARD, of Paris, are manufacturing at their shops at Longueville (Seine-et-Marne) a line of tubings in which there is no soldering, and consequently no seam. These are made from various metals, such as copper, yellow metal, silver, steel, white metal, etc., in an infinite variety of forms and dimensions of cross-section, and the method of manufacture permits of their being produced of considerable length. We have endeavored, in the accompanying cut, to figure a portion of these numerous sections, but it is evident that the diversity of forms that may be made is unlimited. Nos. 1 and 7 of the cut represent the extreme sections of copper tubes that the manufacturers always



CROSS-SECTIONS OF SEAMLESS TUBING.

have in stock. They vary from one-fifth inch to one inch in external diameter. These tubes are round and corrugated (Nos. 8 to 12), or square with sharp angles (Nos. 19 to 23), or square with re-entrant angles (Nos. 24 to 26), or square with figured sides (No. 27). There are also hexagonal tubes (Nos. 28 to 30), oval tubes (Nos. 31 and 32), round thick tubes of small bore (Nos. 33 to 35), flattened ones, smooth (Nos. 39 and 40), or figured (Nos. 41 and 42), or corrugated (Nos. 43 and 44), and finally, triangular (Nos. 36 to 38), etc. The other figures which follow, from No. 45 to No. 88, will give some idea of the multiplicity of styles that are produced by this house.

These tubes are being largely used in various arts and industries, finding application in the manufacture of clocks, musical instruments, optical apparatus, jewelry, etc., and in surgery, pyrotechnics, etc., etc.

Specimens of these tubes were shown at the last Paris Exhibition, both in copper and silver, 1,600 feet in length and seamless throughout their whole extent.

SMITH'S TWO-TON ANCHOR.

THIS anchor is distinguished from those generally employed by the fact that it has no stock, and that the arms are movable on the shank. For this reason it can be constructed without any welding of the parts, its strength being thereby necessarily increased.

The shank, M, is T-shaped, and its lower end is traversed by the axle, N, which moves freely therein, but is fixed firmly to the arms, P P', by bolts. These arms, the form of which is shown in the sections A B and C D, are provided with two claws, R and R', which, when the anchor has been cast and is dragging over the bottom, press against the latter and force the points to incline and grapple the first obstacle that they meet with. The arms are movable only within a certain angle, which is determined by the shoulder pieces with which the shank and arms are provided. The weights are distributed as follows: Shank, 1,700 pounds; two arms, 2,110 pounds; axle, 350 pounds; and rings, 240 pounds—total, 4,400 pounds.

The large companies which have adopted this anchor are the Cunard Company, the Peninsular and Oriental Company, and the Union Steamship Company. The English Navy also uses them on several of its vessels; among others, on the Rover, the Hydra, and the Eclipse.

MECHANICAL REFRIGERATION.

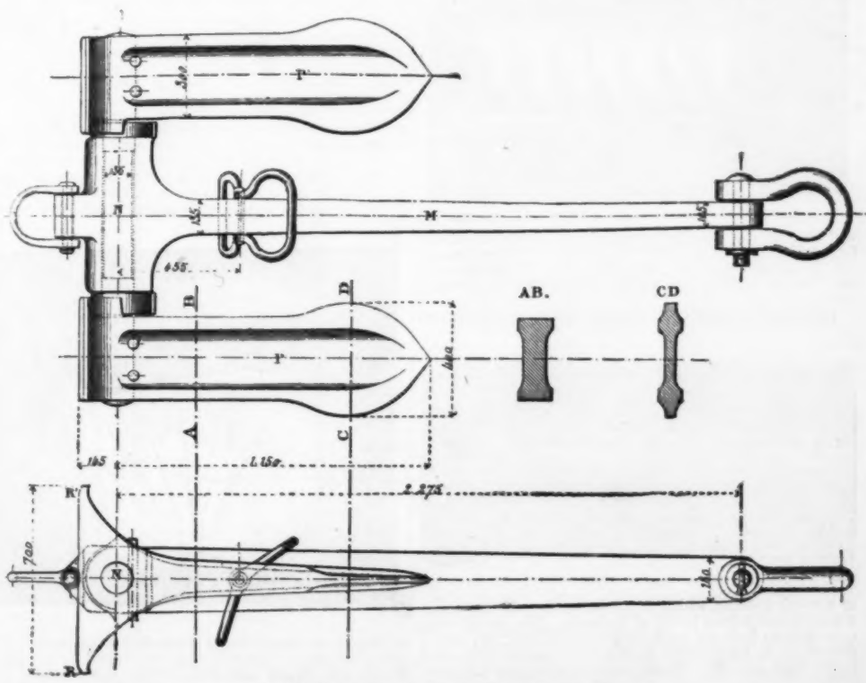
By J. K. KILBOURN.

THE development of machinery and methods for mechanical refrigeration is comparatively speaking of recent date. The different systems now before the public have all been brought out within thirty years. In the laboratories the purely scientific aspects of the various methods are understood, but in the workshop, and with the public generally, they are as a sealed book. The practical information concerning these different systems as yet rests with the few experimenters who have given time and thought to their development. The limits of this article will not permit the writer to speak of the scientific theories of the various systems; but he will confine his remarks to that system and class of machinery where cooling is effected by the alternate compression and expansion of air, leaving it to future opportunity to take up other branches of this subject.

"Regnault's experiments determine that the specific heat of a *given weight* of gas, which is approximately perfect, does not vary with the *temperature* nor with the *pressure* or *density* of the gas;" hence it follows that the potential heat energy of a given weight of air is neither increased nor diminished by any *amount* of compression. In other words, a pound of air at a given temperature, say 60°, will heat or cool any substance having a temperature above or below that of the air, the same number of degrees in every stage of compression, it being immaterial whether the volume is one cubic foot or thirteen. By compressing air, a cooling or condensing medium of comparatively high temperature can be made available, and it has no other object.

By the system under discussion cooling is effected by the transference of heat from the air to be cooled to a cooling or condensing medium, usually water, which when charged with heat is run to waste. The initial temperature of the air to be cooled is raised by compression to such a degree above that of the cooling medium, that in the equalization of temperature heat is abstracted from the air under compression. When expansion follows this cooling, the terminal temperature of the air is the initial temperature minus the heat abstracted, and the heat discharged by the condensing water is the measure of the cooling effected. From the various prospectuses in circulation one might consider that cool dry air was an exclusive production, subject to the pains and penalties of patent monopolies, whereas it is almost a necessary incident to cooling.

Saturated air contains aqueous vapor in quantities varying with the temperature. One cubic foot at 33° having but 2·21 grains, at 50° 4·10 grains, at 100° 19·84 grains, conse-



SMITH'S TWO-TON ANCHOR.

quently reducing the temperature from 100° to 33° causes the liquefaction of 17·63 grains of vapor, which can be collected and removed as a liquid; falling in this, frost and snow are formed, causing no little trouble. Various methods have been devised to overcome this difficulty. In a paper recently read before the Institution of Mechanical Engineers by Mr. Lightfoot, an ingenious arrangement was described. By this method a partial expansion to a predetermined extent reduced the temperature of the air to about 35°. The vapor condensed by this reduction of temperature is deposited on metallic surfaces, collected in suitable receptacles, and run off, after which the air is further expanded to atmospheric pressure. In theory this method appears well; but satisfactory results would require uniformity of temperature in the condensing water not attainable in practical working. In the paper before referred to, the author criticises Bell and Coleman's method of condensing this surplus vapor by a system of metallic pipes; but the objections the author points out cannot be maintained. It is assumed that by both methods the temperature after compression and cooling is the same; then the amount of vapor to be deposited and run off would in each case be equal. By the system of metallic pipes exposed to the action of the spent cold air passing from the chamber, the surplus vapor is condensed and the latent heat of vaporization as well as the heat of the air under compression is absorbed by the "spent cold air" before entering the compression cylinder, and is afterward abstracted and discharged by the cooling water, and every unit so discharged reduces the final temperature of the air after expansion by the same amount.

By the method of condensing the surplus vapor by the "act of expansion" the latent heat of the vapor is taken up by the expanded air, and the final temperature would be raised to the extent of the units of heat taken up, and this result corresponds with the author's statement, that is, with the Bell and Coleman method, the final temperature was 96° below zero, while by the author's system the final temperature was only 68° below zero. By either method, when the excess of vapor over saturation at the temperature has been liquefied and run away, the air is as dry as it can be made by any *mechanical appliances.*

Referring again to Mr. Lightfoot's paper, it appears by the tabulated results of test experiments that a machine that delivers 15,000 cubic feet of cold air per hour with initial temperature of cooling water at 57° requires 23·6 indicated horse power, and for this delivery there was discharged by the condensed water 48,840 units of heat, or an equivalent of making 244 pounds of ice per hour. In other words, by this system 23·6 indicated horse power will produce in 24 hours the equivalent of 52 cwt. of ice, a very low efficiency as compared with the systems using condensible gases as the frigorific medium. The certified results of some of the more volatile of these gases show a production of 12 tons of ice per ton of coal burned. In addition to this low efficiency the excessive weight of the machinery and consequent excessive first cost may be considered as prominent objections to this system; when used on sea-going vessels the fact that every extra ton of machinery or coal excludes a like amount of paying freight adds importance to the objections named. On the other hand, the use of air as the frigorific medium in place of chemicals is an advantage which cannot be ignored, and moreover it is a system easily understood and free from inherent difficulties to overcome in construction.

The advantages and disadvantages are believed to have been fairly stated in the foregoing remarks, and it is hoped that what has been said will make this branch of mechanical refrigeration more clearly understood.—*Engineering.*

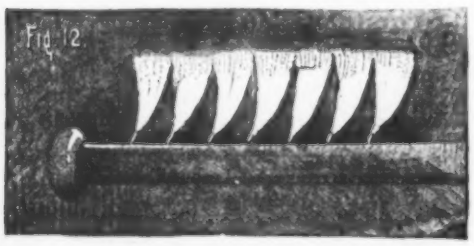
[Continued from SUPPLEMENT No. 278, page 4428.]

SIMPLE HOLTZ MACHINE AND EXPERIMENTS IN STATIC ELECTRICITY.*

By GEORGE M. HOPKINS.

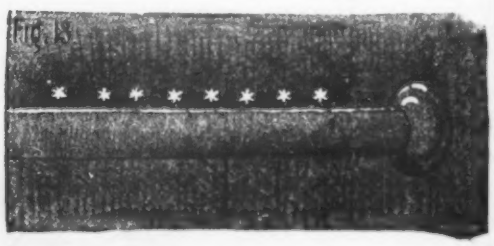
THE simple machine shown in the annexed engraving is nearly if not quite as efficient as the best make, and it is much simpler than the one previously described.

Taking it for granted that the reader is already pretty well acquainted with the essential points of a Holtz machine, I

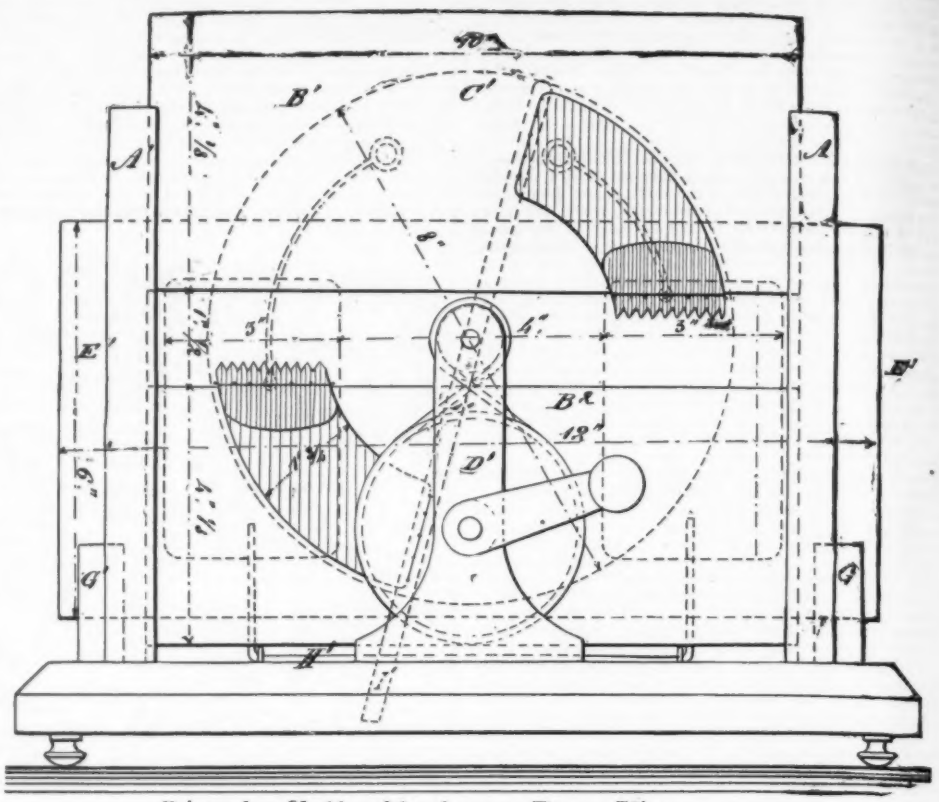


will confine my description mainly to the points of difference between the machine now under consideration and the one before described. As the principal dimensions are given on the engraving, it will be unnecessary to repeat them here.

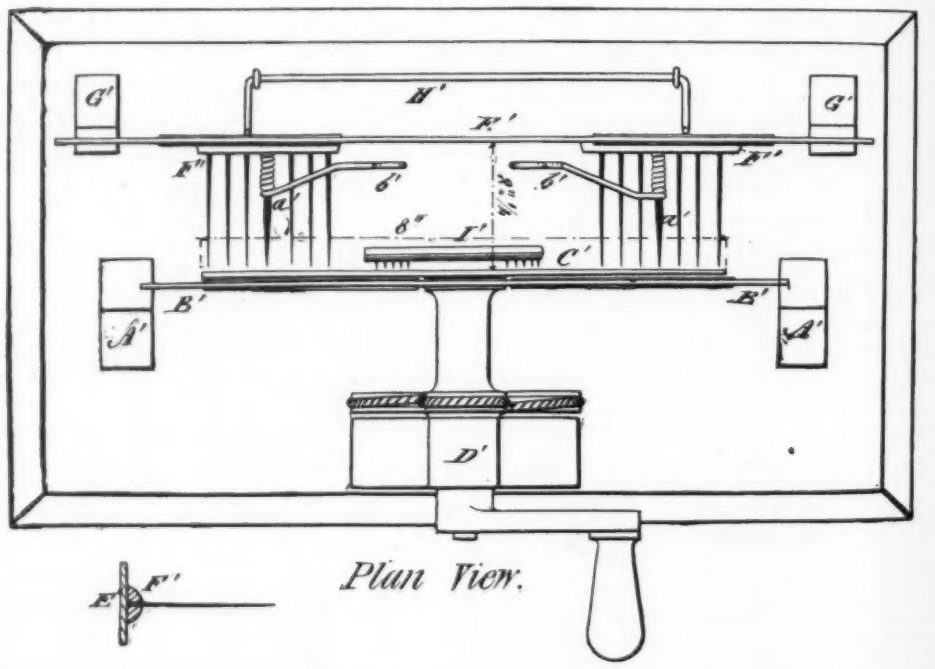
The revolving plate, C', is fastened with cement to the end



of a wooden sleeve, which is similar to an ordinary spool, with a groove turned in one of its heads. This sleeve turns on a quarter-inch pin projecting from the post, D', and is driven by a large wheel having the bearings of its shaft in the same post, D'. This arrangement economizes space,



Simple Holtz Machine Rear View.



Plan View.

and dispenses with one post; but it would probably be better to support the driving wheel on a post of its own. This would admit of using a longer belt and a larger wheel.

As the glass might become loosened if cemented directly to the flange on the end of the sleeve, I first cover the flange with pitch, gutta percha, and shellac cement, and warm it

so that it becomes thoroughly attached to the wood. I then coat a thin disk of leather with cement, and attach it to the flange, and finally cement the leather to the glass. If the leather is of such a porous nature that it does not hold the glass with sufficient rigidity, it is well to apply a little thin shellac varnish to its edges to stiffen it

If the glass does not run truly it may be warmed, and the sleeve may be placed on the pin and revolved, and while the cement is still plastic the glass may be trued up.

Two grooved vertical posts, A', support the two glass plates, B^1, B^2, which in this machine take the place of the fixed apertured plate in the machine described in the former

Fig. 22.

article. They are placed far enough apart to allow the collar of the plate, C', to revolve between them, and they are placed as near the revolving plate as possible without touching.

The paper inductors and gilt paper teeth are formed and applied as in the other case. Instead of the glass posts for supporting the collecting combs, and instead of the Leyden jar form of condenser, a double Franklin plate or condenser, E', is used. This plate is supported in wooden feet, G',

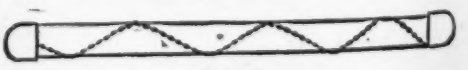


FIG. 23.

and is longer than the plates, B^1, B^2. It has square pieces of tin foil attached to opposite sides near opposite ends. The corners of these pieces of tin foil are rounded to prevent the escape of electricity, and the two pairs of tin foil pieces are placed apart, about half the diameter of the revolving plate, C', and the distance between the inner and outer piece of tin foil

*In the preceding article, on page 4426, in describing the experiment with the folded paper and electroscope, the types say the electricity is "marked;" they should say, the electricity is "masked."

measured around the edge of the glass at any point must of necessity be greater than the striking distance of the machine, to prevent sparks from leaping over from the inside to the outside tin foil coating. The collecting combs consist of bank pins, inserted in half round strips, F', of tough wood, so that their heads are let into the wood, leaving the plain side perfectly smooth. The middle pin, *a'*, is made larger than the rest for supporting the discharge rod, *b'*. The combs

thus made are placed on the glass, E', exactly opposite the edges of the glasses, B', B², at the point where the gilt paper covers it, and the points of the pins must be as near the revolving plate, C', as possible, without touching. Of necessity one of the combs must be the width of the space between the plates, B', B², higher than the other to bring it into the proper relation with the end of the paper inductor, but this is not in the least detrimental.

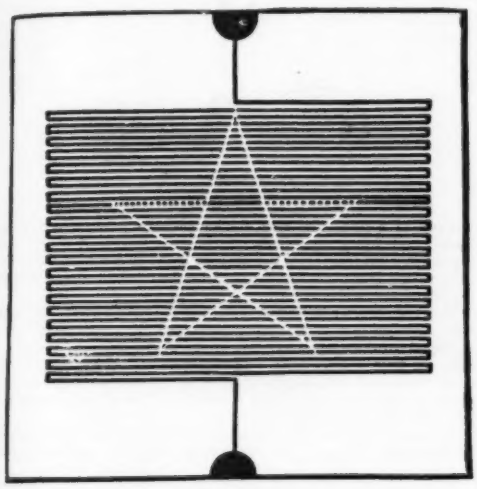
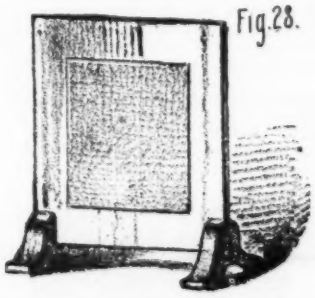


FIG. 25.

A space is cut out of the inner coating of each end of the condenser, E', of the size of the wooden strip, F', forming the base of the comb. The glass at this point is thoroughly cleaned, and the comb is attached with the pitch, gutta percha, and shellac cement. The backs of the combs are then neatly covered with tin foil, which touches the pins and overlaps the tin foil on the condenser. A vertical section of the comb is shown in the detail view.



The discharge rods consist of wires of rather large diameter, say one-eighth inch, wound spirally around the larger pins, *a'*, curved over toward the middle of the machine, and provided with metallic knobs or with rings formed on them and soldered. The knobs are best; common lead bullets answer very well; bullets of type metal are rather better.

The feet, G', may be fixed to the base of the machine or they may be made adjustable

Instead of a chain for connecting the opposite poles of the machine, I use a wire, H', bent twice at right angles and held in position on the base of the machine by two staples.

To get a detonating discharge the wire is allowed to rest against the two outer coatings of the glass. To obtain the silent discharge, the wire is turned down upon the base.

This machine is charged in the same manner as other Holtz machines, and although its plate is only eight inches in diameter, it will yield a spark 2⅛ inches in length under the most unfavorable circumstances. It is probable that if the machine were carefully made and used under favorable conditions it would yield a spark from 8 to 8½ inches in length, and perhaps longer.

The machine represented was made with a view to the utmost simplicity and cheapness, and I might say it was thrown together carelessly to determine how imperfectly the machine could be made and still work. I do not recommend this plan in the construction of the machine, but offer it as a little encouragement to those lacking facilities for doing fine work. Good work is the most profitable in the end, and gives the most satisfaction.

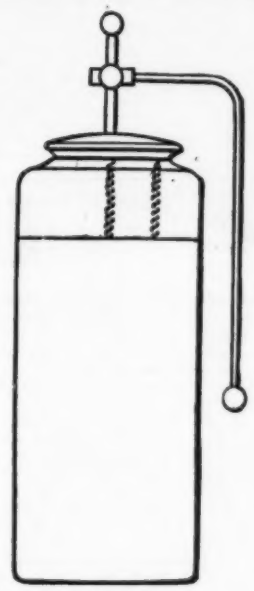


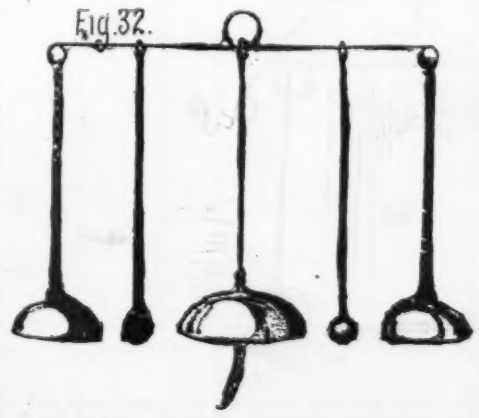
FIG. 30.

Of course this form of machine may be made in larger sizes without difficulty, and fixed plates of this form are very convenient in their application to either single or double plate machines.

As to experiments possible with the Holtz machine, they are

endless. The machine itself presents a weird and interesting appearance in the dark. From the positive comb a luminous brush extends from each point, as shown in Fig. 12. On the points of the negative comb only stars or luminous points are shown, as represented in Fig. 13. Beside these effects the inductors glow with a shimmering, unearthly light, like the aurora. The points of the cross-arm are luminous, and all conducting points near the machine are aglow with the lambent light.

When the machine is at rest, if one hand is placed upon the



negative discharge rod and the other hand is held a short distance above the positive discharge rod, as shown in Fig. 14, and if an assistant turns the machine, beams of soft purple light will radiate from the knob at the end of the discharge rod toward the hand. In this experiment, the chain on the table must be removed from one of the jars. No shock will be experienced during this experiment if carefully conducted.

Geisler tubes are best exhibited by placing them between the jars, I, allowing them to nearly touch the outer coating of the jars. (Fig. 22.) The discharge rods should be placed one-fourth inch apart, and the machine adjusted for the silent discharge. Care should be taken in the use of tubes having long sinuous passages, such as twisted or spiral tubes and the like, as they are very liable to be ruptured by the spark. When such tubes are used, the rods must be as near together as possible without destroying the effect.

FIG. 33.

Another method of exhibiting Geisler tubes is to hold them, in the hand parallel with the face of the revolving plate, and about three or four inches from the large balls through which the discharge rods pass.

When the electric discharge is over an interrupted conductor, a bright spark appears at every interruption. Fig. 23 shows a tube wound spirally with a narrow strip of tin foil, cemented to it with starch paste, stratena, or shellac varnish. After the cement is thoroughly hard, the tin foil

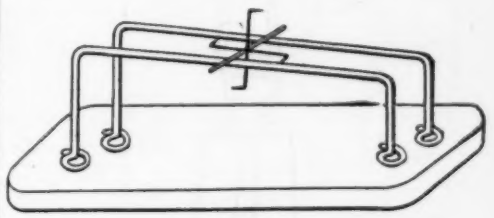


FIG. 34.

is separated at short intervals, say one-quarter inch, with a knife or file, leaving a narrow space of about one thirty-second inch between the sections. This tube may be from twelve to eighteen inches long, and for the sake of protection may be inclosed in another glass tube. A strip of foil should extend from the extremities of the interrupted strip over the ends of the outer tube. The inner tube may then be stopped with a cork at each end, which is allowed to project a short distance. These corks are rounded at their

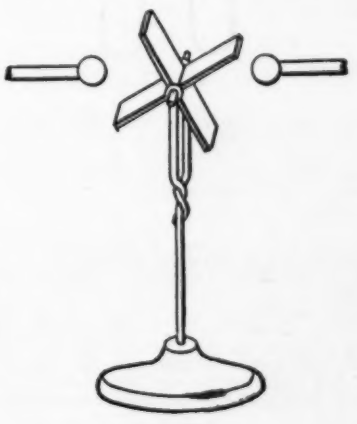


FIG. 35.

outer ends, and covered with rather thick tin foil, which is allowed to extend a short distance over the end of the outer tube. This tube, held by one end in the hand and presented by its other end to one of the conductors of the machine, exhibits a brilliant luminous spiral. The brilliancy of the sparks may be increased by connecting the discharge rods with the ends of the tube.

Fig. 24 shows a zigzag strip of tin foil cemented to a plate of glass about a foot long. The strip is interrupted as in

FIG. 36.

the case of the spiral tube, and the ends of the strip are connected with large patches of tin foil pasted over the edge of the glass. This plate is very brilliant when the ends of the interrupted strip of foil are connected with the electrodes of the machine.

The star shown in Fig. 25 is made by running strips of tin foil back and forth over the face of a square of glass, and interrupting the strips in the manner already described. The spaces between the strips must be three or four

times greater than the interruptions of the strip, to prevent the spark from jumping laterally from one strip to another. In all of these cases of interrupted conductors, the pieces of tin foil may be put on separately if desired, but I have found it more convenient to put on the strips as described.

The Franklin plate or fulminating pane, shown in Fig. 28, is made by attaching sheets of tin foil to opposite sides of a pane of window glass, leaving a space of two inches all around. It will be found convenient to support the glass upon two wooden feet, as shown in the engraving. This plate is charged by connecting the tin foil on one side with

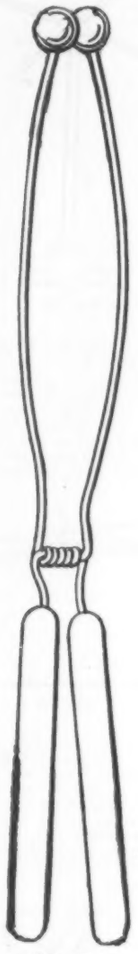


FIG. 37.

the ground, and that upon the other side with one of the conductors of the machine. It is discharged by touching opposite sides with a discharger. By connecting opposite sides of the plate with the opposite conductors of the machine the plate may be charged so that it will discharge over its edges with a loud report

The Leyden jar, shown in Fig. 29, is nothing more than a fulminating pane rolled up. It may be made by covering a jar over the bottom and about half way up its sides with tin foil, and stopping the mouth of the bottle with a well varnished cork or wooden stopper, through which runs a one-eighth inch wire, having a knob on its upper end, and a piece of chain on its lower end resting on the tin foil lining. It is well enough to varnish the uncovered portions of the glass jar with shellac varnish. The jar may be made in various sizes, and when the size is so small that it is inconvenient to apply tin foil to the inside, a little shellac varnish

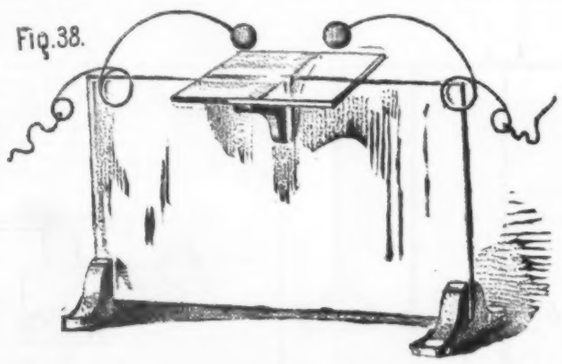


FIG. 38.

may be poured into the bottle, and the bottle coated half way up its sides with the varnish by turning it down upon the side and revolving it. Before the varnish begins to dry a quantity of metal filings are poured into the bottle and shaken about. They attach themselves to the varnish and form a metallic coating that answers a very good purpose. When the varnish dries the surplus filings may be poured out and the bottle may be coated with foil on the outside.

The jar is charged by connecting the outer coating with the ground or with one of the conductors of the machine, and connecting the ball with the other conductor; and it is discharged by touching the ball and the outer coating of the jar with opposite ends of a jointed discharger.

The measuring jar, shown in Fig. 30, is similar to the jar just described, the only difference being the addition of a curved wire having a ball on its lower end, and a support for the wire attached to the vertical discharge wire of the jar. The ball of the additional wire may be placed a greater or less distance from the outer coating of the jar, and it will be obvious that the jar can never be charged to give a spark longer than the distance between its outer coating and the ball.

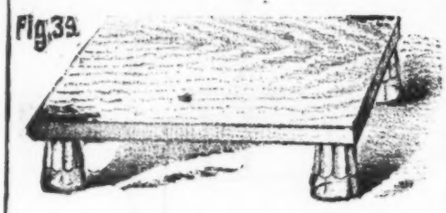


FIG. 39.

The disruptive effect of the spark can be readily exhibited by partly filling a glass bottle (Fig. 31) with olive or lard oil, and inserting through the cork a curved wire pointed at its lower end and provided with a ball at its upper end. The pointed end of the wire should be very near the inner surface of the glass, and the ball at the top should be connected with one of the conductors of the machine. The other conductor should be placed opposite the point of the wire and near the side of the bottle. The jointed discharger may be used to good advantage in this experiment.

When the machine is turned the sparks will perforate the glass, and will continue to pass through until the pointed wire is turned to a new place in the bottle, when another hole will be made. The holes made by the spark are so small that the oil will pass through very slowly, if at all.

Figure 33 shows a chime of bells operated by the electric discharge. The three bells are suspended from a wire cross arm, which is supported by one of the discharge rods of the machine or by an insulated support connected with the machine. The two outer bells are suspended with chains, the middle one with a silk cord. Two small metal buttons are suspended by silk threads half way between

FIG. 40.

the outer bells and the middle one, and the middle bell is provided with a chain which rests on the table.

When the machine is turned the suspended buttons are attracted to the outer bells, and after becoming charged with electricity are repelled by the outer bells and attracted toward the middle one. After parting with their charge they are again attracted by the outer bells, again repelled, and so on. If the bells are connected with the ball of a Leyden jar, and the chain from the middle bell is connected with the outer coating of the jar, a slow discharge of the jar will take place; and the time occupied in the discharge may be prolonged by fastening up one of the buttons so that it will not swing.

The electric fly, shown in Fig. 33, illustrates the effect of the electric discharge from points. The fly consists of a piece of metal having a slight depression in the center to receive the pivotal point on which it turns, and having a number of wire arms, pointed at their outer ends and all bent in the same direction. When the pivot of the fly is connected with the machine, the fly revolves in a direction opposite to that of the points. The motion is owing to a repulsion between the electricity of the points and the electricity imparted to the adjacent air by conduction.

Fig. 34 shows a fly mounted on a horizontal axis, the latter being placed on two inclined wires having feet resting on a pane of glass. On connecting the incline with the machine the fly will revolve and ascend the inclined plane in opposition to gravity. When electricity escapes by a point the electrified air is repelled so strongly as to blow out a candle or turn a fan wheel.

Fig. 35 shows a light fan wheel having its wings or floats made of paper. This wheel when presented to a point on the machine, or when placed between the discharge rods as shown in the engraving, will be made to revolve by the current of electrified air.

Fig. 36 represents a simple apparatus for demonstrating the repellent action of similarly electrified molecules. A piece of thermometer tube whose caliber is just sufficient to permit water to pass through it slowly, is inserted in the

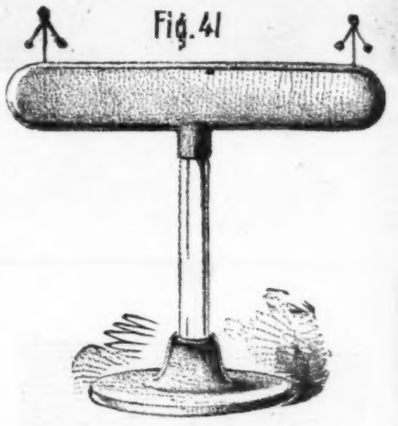


FIG. 41.

bottom of a small tin pail. The pail is partly filled with water and hung upon one of the discharge rods of the machine. So long as the water remains in a neutral state it only drops from the capillary tube, but when the machine is turned the water runs in a stream.

For various experiments with the electrical machine and with Leyden jars a jointed discharger is very convenient. A simple and inexpensive one is shown in Fig. 37. It consists of two wires bent one around the other to form a joint, and bent out nearly parallel in one direction to secure wooden handles, while the opposite extremities are curved and provided with balls at the ends.

In many experiments in static electricity the wires must terminate in balls, to prevent escape and to secure the desired form of spark, and as it is a matter of considerable labor to make a large number of metal balls on the lathe, I have adopted the expedient of casting the balls directly upon the wires, using an old-fashioned bullet mould with a hole drilled in the bottom to receive the wire upon which the ball is cast. Type metal is excellent for this purpose, but lead will answer very well. An alloy of tin and antimony makes a very fine ball that may be lacquered to look like brass.

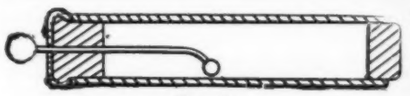


FIG. 42.

In a certain class of experiments the universal discharger is convenient if not absolutely necessary. A cheap and simple form of this instrument is shown in Fig. 38. It consists of a pane of glass a foot long and six inches high, supported on wooden feet. Upon the upper edge in the

FIG. 43.

center there is a glass table supported by two wooden brackets cemented to both glasses. Upon opposite corners of the upright glass there are two curved wires bent into the form of a spring in the middle to clasp the glass, and having at their upper ends balls and at their lower ends rings to receive the conductors which connect it with the machine. By means of this instrument the electric discharge may be made to pass through any substance placed on the glass table.

The simplest method of making an insulating stool for supporting a person while being charged with electricity is shown in Fig. 39. It consists of a board supported by four common tumblers. An insulated spherical conductor is

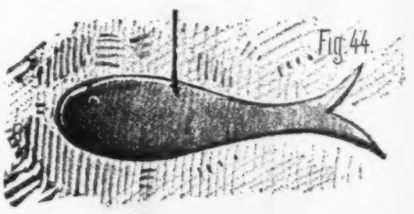
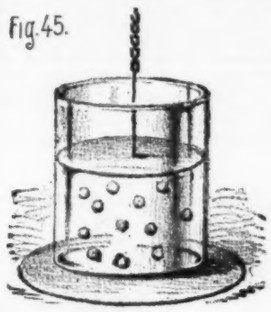


FIG. 44.

shown in Fig. 40. It may be made of any thin metal or of a pasteboard ball covered smoothly with tin foil. Probably the cheapest article for this purpose is the copper ball float sold by plumbers. This sphere is supported upon a glass standard inserted in a wooden base. The ball is five to six inches in diameter. Fig. 41 shows a cylindrical conductor about four inches in diameter and twenty inches or two feet long. It has rounded ends, and is supported on a glass standard at the same height as the spherical conductor. With these two conductors the phenomena of static induction may be exhibited. From each end of the cylindrical

conductor a pair of pith balls should be suspended by silk threads, and a pair of pith balls should also be suspended from the center of the conductor. Now, by charging the spherical conductor with positive electricity, and bringing it within a few inches of one end of the cylindrical conductor, the pith balls at the ends of the latter will diverge, while

Fig. 45.

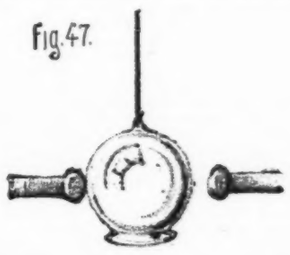


those at the center will remain quiet. By applying the test given in the early part of the former article it will be found that the electricity of the end of the cylindrical conductor nearest the sphere is negative, while that of the remote end is positive.

Fig. 46.

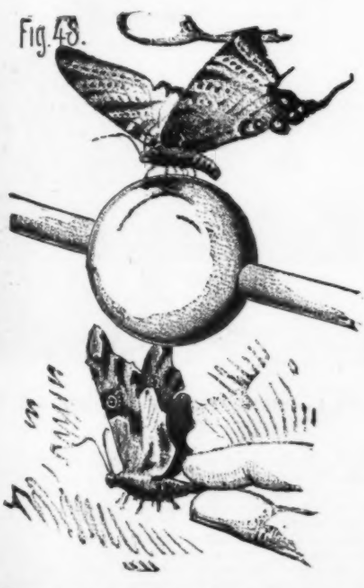
Fig. 42 shows a gas pistol, consisting of a metallic tube permanently stopped at one end with insulating material, and having a wire inserted in the stopper and nearly touching one side of the tube. The tube is filled with a mixture of illuminating gas and air, and lightly stopped with a cork.

Fig. 47.



An electric discharge through the wire and tube explodes the charge of gas. Fig. 43 shows a somewhat similar device for exploding gunpowder. It consists of a block of wood having a central cavity into which are inserted two wires nearly touching. The powder is placed in the cavity,

Fig. 48.



and the spark sent through the wires, in leaping the space between their inner ends, ignites the powder.

The fish shown in Fig. 44 is of pasteboard covered with gilt paper and suspended by a silk thread. When its pointed tail is presented to the conductor of the electrical machine it is repelled, but its rounded head is attracted.

Fig. 45 represents a simple apparatus for exhibiting the alternate attraction and repulsion of pith balls when placed between two metallic plates connected with opposite conductors of the machine. To prevent the pith balls from flying in all directions they are confined by the glass jar. Four pieces of window glass forming a hollow square may replace the jar in this experiment.

Gassiot's cascade, shown in Fig. 46, is a beautiful experiment, but requires an air pump. A goblet coated with tin foil in the manner of a Leyden jar is placed under the tubulated bell of an air pump; a rod extends through the bell into the goblet, and when the electric discharge takes place (the rod and plate of the air pump being in communication

Fig. 49.

with the machine), a cascade of wavy light overflows the goblet like a fountain.

The glass globe (Fig. 47) is suspended by a silk thread between the discharge rods of the machine. If started it will continue to turn in the direction in which the electric discharge takes place. If vertical strips of tin foil are fastened on the globe at short intervals it will revolve without external aid.

The paper butterflies (Fig. 48), when held in the manner indicated, will flutter in a most natural way.

The pith ball electroscope, shown in Fig. 49, consists of a rod having at its upper end a ball and at its side a scale, from the angle of which is suspended a pith ball on a fila-

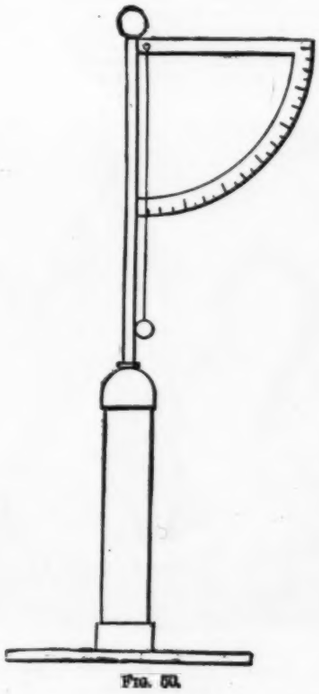


Fig. 50.

ment of whalebone. The upper end of the whalebone is formed into a loop which hangs on a delicate pivot projecting from the scale. This instrument placed on a body receiving an electric charge will indicate the extent of the charge.

Fig. 50 shows a double pith ball electroscope with a standard.

What has been said covers a very small proportion of the possible experiments in static electricity; but it is hoped that some of the hints given above in regard to the construction of the electrical machine, and some of the apparatus to be used in connection with it, will enable the student of electricity to at least begin a course of experiments which will prove of absorbing interest.

CHEMICAL ENERGY AND ELECTROMOTIVE FORCE OF DIFFERENT GALVANIC COMBINATIONS.

By JULIUS THOMSEN.

IT has hitherto been difficult to determine whether the whole or only a portion of the energy produced by chemical action is converted into electricity, for want of sufficiently accurate measurements of the heat corresponding with the chemical reactions. The author is now able to solve this problem, using his recently thermo chemical results. The first condition, that all chemical energy can be converted into electricity is that no chemical action must take place when the circuit is broken, a condition realized in the so-called constant batteries. The current from a Daniell's cell was made to pass through a calorimeter containing four platinum spirals, and the quantity of heat produced by the current measured, the current itself being also measured on a sine galvanometer, the absolute value of the deflections of which were known by a previous comparison having been made with the corresponding quantities of gas given off in a voltameter. The resistance of the Daniell's cell was also determined, so that the total quantity of galvanic heat produced in a given time could be calculated. Knowing the absolute value of the current flowing during this time, the amount of chemical decomposition going on in the Daniell's cell could be calculated, and its heat equivalent determined from the author's recent experiments on the heats of combustion. And it was found that in the case of a Daniell's cell the galvanic heat or heat generated by the current flowing through resistance was practically equal to the whole of the heat that would have been produced by the chemical decomposition in the cell had the chemical reactions taken place without production of electricity, the two numbers being 50,292 in the first case and 50,130 in the second, or practically the whole of the chemical energy in this case is converted into heat.

The author next compares the chemical energy and the E.M.F. of different galvanic combinations, and the results are shown in the following table:

	Voltaïc Combination.	Its Chemical Reaction.	Corresponding production of Heat.	Energy of the Combination. Absolute.	Energy of the Combination. Heat of Daniell's Cell as unit.	Name of the Inventor.
1	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,000	50,130	1·00	Daniell
	Sulphate of copper / Copper	− (Cu, O, SO_3 Aq)	− 55,960			
2	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,090	16,580	0·33	Regnault
	Sulphate of Cadmium / Cadmium	− (Cd, O, SO_3 Aq)	− 89,600			
3	Zinc / Hydrochloric acid	+ (Zn, Cl_2 Aq)	+112,840	54,080	1·08	Pincurs
	Chloride of silver... / Silver	− (Ag_2, Cl_2)	− 58,760			
4	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,090	98,090	1·92	Bunsen
	Nitric acid hydrate / Carbon	− (N_2 O_4, O, H_2 O)	− 10,010			
5	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,090	82,810	1·65	Bunsen
	Dilute nitric acid... / Carbon	− ½(N_2O_5,O_5,7H_2O)	− 23,280			
6	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,090	99,790	1·99	Bunsen
	Chromic acid / Carbon	− ½ (Cr_2 O_3, O_4 Aq)	− 6,300			
7	Copper / Sulphuric acid	+ (Cu, O, SO_3 Aq)	+ 55,960	45,880	0·91	Thomsen
	Nitric acid hydrate / Carbon	− (N_2 O_4, O, H_2 O)	− 10,010			
8	Iron... / Hydrochloric acid	+ (Fe_2, Cl_2 Aq)	+ 99,960	44,430	0·88	Fonzi
	Perchloride of iron / Carbon	− (Fe_2 Cl_6 Aq Cl_2)	− 55,530			
9	Zinc / Sulphuric acid	+ (Zn, O, SO_3 Aq)	+106,090	37,720	0·75	Wollaston & Sömerne
	Platinum /	− (H_2 O) ½	− 68,360			

Lastly, the author compares the calculated E.M.F. with the actual electromotive force, and the amount of accordance of the numbers given in the last two columns of the following table shows what proportion of the total energy of the cell is converted into electricity:

	Combination.	Chemical Energy. Absolute.	Chemical Energy. Relative.	E.M.F.
1	{Zn—H_2 SO_4 + 100 H_2 O} {Cu—conc. Cu SO_4 Aq}	50,130	1	1
2	{Zn—H_2 SO_4 Aq} {Cd—conc. Cd SO_4 Aq}	16,580	0·33	0·33
3	{Zn—H Cl Aq} {Ag—Ag Cl}	54,080	1·08	1·055
4	{Zn—H_2 SO_4 + 100 H_2 O} {C—HNO_3}	96,080	1·91	1·66
5	{Zn—H_2 SO_4 + 100 H_2 O} {C—HNO_3 + 7 H_2 O}	82,810	1·65	1·69
6	{Cu—H_2 SO_4 + 100 H_2 O} {C—Cr_2 O_6, SO_3 Aq}	99,790	1·99	1·95
7	{Zn—H_2 SO_4 + 100 H_2 O} {C—HNO_3}	45,950	0·92	0·88
7b	{Cu—H_2 SO_4 + 100 H_2 O} {C—HNO_3 + 7 H_2 O}	33,680	0·65	0·73
8	{Fe—Fe_2 Cl_6 Aq} {C—Fe_2 Cl_6 Aq}	44,430	0·89	0·90

—*Annalen der Physik und Chemie.*

TEMPERATURE OF THE ELECTRIC LIGHT.

By FR. ROSETTI.

FROM experiments with 160 Bunsen elements with Duboscq's lamp, it appears that the temperature of the positive carbon lies between 2,400° and 3,900° C. It is so much the higher the smaller the radiating surface, supposing that the surface includes the extreme point; the temperature of the negative electrode varies between 2,138° and 2,530° C. Hence the temperatures of the extreme points of the electrodes are not below 2,500° and 3,900° C. In a Reynier lamp connected with 8 to 10 Bunsen elements, the temperature of the positive carbon amounted to 2,406°—2,754° C.—*Atti. dell Jor. Veneto.*

PHYSICS WITHOUT APPARATUS.

THE following are a few more simple experiments in physics belonging to the excellent series hitherto published, and for which we are indebted to our French contemporary *La Nature:*

Take a ten cent piece and place it flat against a vertical piece of wood, such as the upright of an oak set of bookshelves, for example, rub it briskly up and down, all the time pressing it firmly against the wood. In a few moments remove the hand and the piece of money will be found fast adherent to the wood. The reason is this: By the friction and the pressure exercised the thin layer of air between the coin and the wood has been expelled, and the pressure of the external atmosphere suffices to hold the coin in place. (Fig. 1.)

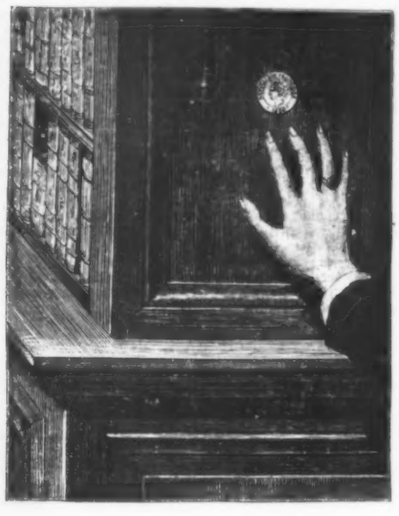


FIG. 1.—SILVER COIN CAUSED TO ADHERE TO WOOD BY PRESSURE OF THE AIR.

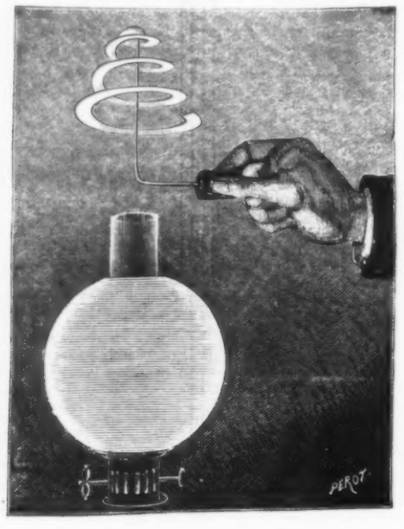


FIG. 2.—PAPER SPIRAL ROTATED BY A CURRENT OF HOT AIR.

FIG. 3.—NAPKIN RING RAISED BY CENTRIFUGAL FORCE.

The experiment represented in Fig. 2 is an interesting one and may be varied in different ways. Cut out of a playing or visiting card a spiral, and then elongate it in such a way that the center may pivot on the end of a piece of wire bent at right angles. If the spiral be placed over a current of hot air, such as that which ascends from a lamp chimney, it begins to revolve quite rapidly. The spiral may also be placed, with its support, on a hot stove and made to revolve in the same manner. This experiment, though simple and often performed, may give occasion for a short lecture on the inclined plane, the motion of the air, the transformation of heat into motion, etc.

These two experiments are very easy of execution, and any one can perform them without risk of failure or without preliminary practice; but not so with the one shown in Fig. 3. This consists in raising a napkin-ring by making it revolve around the forefinger. The experiment is difficult and requires a quick hand and some practice, but we have seen it succeed perfectly. The forefinger is placed vertically in the middle of the ring (which should be light and of as little bulk as possible) and twirled around as rapidly as possible. Through the action of centrifugal force and the resistance of friction the ring may be at length lifted with the finger in rotation as the latter is gradually raised. It is not impossible to lift the ring thus over the neck of a bottle and then allow it to drop thereon. This little trick is one of those sometimes performed at the table after dinner; but, aside from its trivial character, it may prove the object of interesting physical considerations.

We have already published many experiments in regard to center of gravity, and have given several curious examples of equilibrium; here is another, however, which is quite novel and easy of success. Thrust a piece of bent wire or a bent nail into the end of a key, and tie the hooked end of the wire or key firmly to a wooden ruler. From the lower end of the ruler suspend a weight of, say, two to three ounces. Then embed a large-headed pin in the top of a table, near the edge, and carefully adjust the handle of the key on the head of the pin so that the whole affair shall be in equilibrium, as shown in Fig. 4. The key may then be made to pivot on its narrow support without falling off. It is scarcely necessary to explain that this is due to the fact that the weight, the center of gravity of the affair, is, through the inclination of the ruler, situated directly under the point of suspension. Very often at fairs and industrial exhibitions crowds of persons will be seen attracted before those curious concave and convex mirrors which cause the observer to assume most grotesque forms. The same optical phenomena, however, may be shown by simpler methods at home. It is sufficient, for instance, to look at one's self in a highly polished spoon, or, better, in a silver coffee pot, to see the same effects. The convex side of a silver coffee pot makes an excellent convex mirror, and when the hand is placed near it, the image of the latter will appear enlarged and deformed, as shown in Fig. 5. The most remarkable and brilliant phenomena are not always those which require the most complicated pieces of apparatus. What is prettier than a soap-bubble, which is so easily formed at the end of a straw (Fig. 6)? At its inception, when the liquid sphere is yet of only a small diameter, the film is colorless and transparent. Little by little, as it becomes inflated with air, the diameter increases at the expense of the thickness; and, as the tenuity increases, a most brilliant series of colors begins to play over the surface of the sphere, forming by their admixture a multitude of iridescent tints. This experiment, so simple and childish, which offers so many attractions to an artist who loves colors, is none the less beautiful and less interesting to the eyes of the savant. Newton made it the object of his studies and meditations, and since his time the colors of the soap-bubble have held a legitimate place among the curious phenomena of optics, and are studied under the name of "Newton's Rings"—the phenomenon which results from the interference of light falling on thin films. There are few futile observations in the study of the material world. Galileo discovered the laws of the pendulum by watching the swing of a lamp in a church; Newton unveiled the principle of universal attraction by seeing an apple fall; and Pascal was led to study the laws of acoustics by hearing the resonance of a faience plate that somebody accidentally struck with a knife while seated at the table.

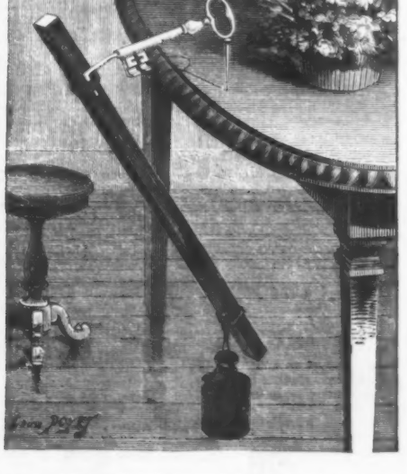


FIG. 4.—EXPERIMENT ON CENTER OF GRAVITY.

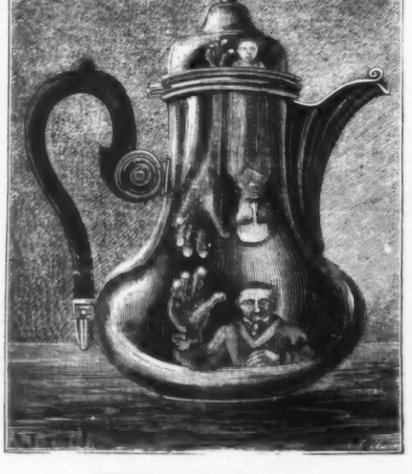


FIG. 5.—CONCAVE AND CONVEX MIRRORS SHOWN WITH COFFEE POT.

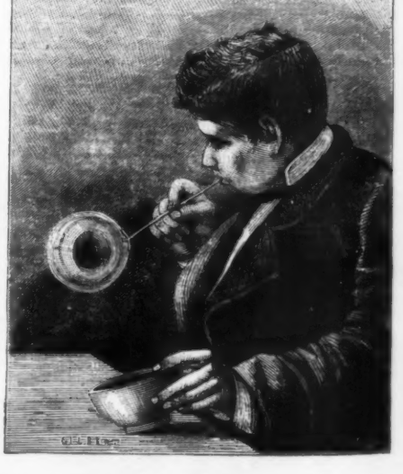


FIG. 6.—PHENOMENA OF COLORED RINGS.

THE PAST IN THE PRESENT.

THE curious persistence of barbaric customs side by side with the highest civilization has been noted by many. Some interesting illustrations of this tendency of the poor and the uneducated to resort to or retain archaic tools, implements, and modes of living, are given by Prof. Arthur Mitchell in a recent work on "The Past in the Present."

Speaking of the favorite idea of to-day, that man is in a state of constant progression, Prof. Mitchell says:

"The tendency to go on forever becoming something better and nobler does not exhibit itself in the history of man, so far as we know it. . . . A social organism, like an individual organism, undergoes modifications until it comes into equilibrium with environing conditions, and thereupon continues without further change of construction. When the conditions are changed meteorologically or geologically, or by alterations of flora or fauna, or by migration consequent on pressure of population, or by flight before usurping races, or by other such things, then some change of social structure is entailed. But this change does not necessarily imply advance. Often it is toward neither a higher nor a lower structure. When the habitat entails modes of life that are inferior, some degradation results."

Reviewing at length Prof. Mitchell's work, the *Times* remarks that we cannot afford, in the interests of truth, to be in the least sentimental in our treatment of a problem of this character. The deductions drawn from the best modern thought, without the use of examples, indubitably lead to an opinion of this character. A man must be ignorant of history who cannot see for himself how the degradation of races, cultured or civilized (we will not dispute as to the meaning of these little-understood words), has come to pass. Highly evolved societies, such as the Egyptians, Babylonians, Assyrians, Phœnicians, Persians, Jews, Greeks, and Romans, Mr. Spencer bids us look at. They "have disappeared or have dwindled to barbarous hordes, or have been long passing into decay." The ruins of Java, of Peru, of Mexico, of Central America, show that a teeming population, highly cultured, once existed, of which not a trace remains to-day. Mr. Spencer further points out that the tribes now known as lowest sometimes exhibit social phenomena which are due apparently not to causes now operating, but to causes that operated during past social states higher than the present. If we can put any faith in historical evidences, there was a civilization in Southeast Africa existing as late as the seventeenth century, which has fallen away and quite disappeared to-day. Why need we

go to another continent for this lesson? Did it not exist in the deserted pueblos found in our own southwestern country? Sorely has this question of degradation puzzled the abilities of the greatest minds, and Humboldt and Niebuhr are both inclined to think that savages are the degenerate remnants of more civilized races.

Passing from the conclusions arrived at in "The Past in the Present," the *Times* endeavors to explain some of the illustrations used by the author, which mainly tend toward showing that not a few of the relics of a past age exist to-day.

Visiting Fetlar, one of the Shetland group of islands, the author meets a boy giving shape to something with a pocket-knife. Being asked what he is making, he replied: "A whorl for his mother." Finding the mother of the lad, she produces two spindles, each with a soapstone whorl. It is a circular bit of stone which slips on the light wooden spindle, and by its weight, when once put in movement, keeps up the motion as would a fly-wheel. Here the author acquires a lesson of caution which antiquarians should remember. Here is what is believed to be one of the oldest of objects, something found in Anglo-Saxon and Carlovingian graves, in Swiss lacustrine finds, in the so called Troy of Schliemann, in the Egyptian tombs, in the Mound-builders' graves of Ohio, which was thought to have belonged to a past and forgotten time. It is in use by a woman on the very outskirts of the greatest civilized center the world knows of. The housewife is still working her wool or flax by a method thousands of years old. From having once been used by every woman who made yarn or thread in England, the whorl has been forgotten by generations of later spinners, until to-day only, perhaps, in an isolated spot in the Shetland Islands it has survived.

There is degradation even in this poor bit of stone or lump of clay, for Prof. Mitchell finds that at Islay, within fourteen miles of Inverness, a woman, instead of the stone, used a piece of potato. The spinner knew nothing about a stone—had always used the potato. When an old art wanes there is then degradation of the object. This point of a falling off from a higher special standard, the author frequently illustrates. Take the discovery of printing, and consider the influences it had on manuscript. Whenever books are multiplied less labor and skill is used in their manufacture. Such manuscripts as were once produced no longer exist. A curious example is deduced from the samplers. Once careful needlework was combined with excellent design. Dr. Balfour shows the author five samplers, the work of five generations of women in one family. They are dated, but it was not necessary to look at them for chronological indications. The nearer they were to us the worse they were. "Sampler work was dying out, and death came to it in the usual way, by a process of degradation." Woven stuffs, made with handsome designs, were better, cheaper, and sampler work was useless. Must we, then, despise the whorl? Was primitive man a stupid creature for having invented and used it? Why, it is used to-day in India, and attached to a crude spindle, a simple splinter of cane, with a pellet of clay, those marvelous muslins of Dacca, with the poetic names of the Evening Dew, the Running Water, the Woven Air, are made, and neither Manchester nor Lowell can imitate them. We have no right, then, to speak of these whorls or spindles as the implements of barbarous and uncultured people, for we know that they are capable of supplying the material for either coarse fabric of the Shetlander or that diaphanous tissue which but half conceals the charms of the Oriental houri. Neither the simplicity nor the antiquity of the contrivance would necessarily show its employer to be wanting in culture or in capacity. We ourselves might be called of the stone or the bone age, and therefore degraded intellectually, because our glazier cuts his glass with a stone, or for the reason that the writer of this cuts the leaves of his book with an ivory paper-knife. We have the choice of material, that is all, which primitive man had not.

"There is sometimes," writes Professor Mitchell, "an unwillingness to look at all sides of objects classed as ancient, lest something should be discovered which might reduce their age, and render them possibly modern and commonplace." The love of the wonderful is inherent, and certainly shows itself, and there is disinclination to accept what may overthrow cherished opinions.

In the Island of Lewis, in driving from Uig to Barvas, Prof. Mitchell sees a stone-breaker eating his dinner from a remarkable vessel. The strange vessel is purchased, and the author finds out where the craggan, as it is called, is made. It is a woman who is the potter in the village, and she makes a craggan for her visitor. She takes the coarsest clay, uses her fingers, a stick, and constructs one. It is allowed to dry for a day or so, and then fired by building up burning peats around it. As soon as it is taken from the fire, the workwoman slowly pours about a pint of milk in it in order to make it less porous. "The rudest pottery ever discovered among the relics of the stone age is not ruder than this, and no savages now in the world are known to make pottery of a coarser character." Suppose fragments of a craggan were brought before a society of archæologists. The chances would be very great that their decision would be that these potsherds were the outcome of a people who were clad in skins, eating raw flesh, and utter barbarians. But the woman who made this poor ware was a Christian, and around her in her wretched cabin were the evidences of the civilization and commerce of the present century. Her surroundings might have been miserable; still, there was cotton from America, sugar from the West Indies, tea from China, and tobacco from America. All she did was to repeat what had been done in prehistoric Scotland, and here was the overlapping of the past in the present. So we may have in a limited area the choicest Sèvres china and the crudest earthenware crock—the first, the sum total of all the experiences of science and art, and the last indicative of the methods used by man when he first made a poor pot. Passing by the quern, the primitive hand-mill for grinding corn or oats, which shows survival of the earliest method, of the knockin' stane, used for dressing barley, a rude stone mortar with a stone or wooden mallet, both still in use, we come to some strange aberrations of taste which Prof. Mitchell develops from the use of these vessels or implements. The woman who made the craggan did, we should suppose, the very worst thing with her earthenware pot when she poured milk into it. It might have stopped the pores, but the albuminous matter, absorbed by the clay, would be sure to decompose, and would taint all other fluids placed in the vessel. Now, the result would be that as all milk put in a craggan would become tainted, a liking for a badly flavored milk would be produced. Therefore, in the Shetland Islands, tastes have been trained to like this tainted fluid. The cultivation of a peculiar taste for unsavory things finds an illustration in the use of game which, when decomposed, intelligent people still eat. It is a flavor which is fashionable. "With such facts as these in mind, is it not unsafe to draw strong conclusions as to the intellectual state of savages from the fact that we find many of them eating and relishing food which we detest?"

In Shetland, from the uncertain character of the harvest, corn is often plucked barely mature, not fully dried, and necessity requires that it shall be consumed at once. It is dried by roasting, either in a kettle or on a hearth, by rolling hot stones on it. It seems perfectly natural that this must have been a primitive method. The corn thus prepared is called burstin. Of course, some of the grains are burned, but it is too precious to waste or maybe too troublesome to separate, and so all are incorporated in the same bread. The taste could not be agreeable to us, but habit had made the taste, and what originated by accident or imperfect preparation, when man first grew oats or barley, has been retained and accepted. African travelers tell us of Zulu women carrying water in ostrich eggs in the openings of which a tuft of grass has been put. Prof. Mitchell, who has an eye for the picturesque, draws a charming picture of a Lewis girl, handsome, healthy, bare-legged, who carries on her back an open creel half filled with heather, and in it nestled two large globular craggans full of milk, each with its mouth stopped by a handful of freshly pulled grass. As she passed she was unconscious of being in the professor's eye an archaic maid.

Passing rapidly over the black houses of Lewis, made of rough cobble-stones, thatched with sod, and the bee-hive houses of Loch Roag—these are described as being absolutely the same structures as were built in prehistoric times—only people live there to-day, and are born and die there—Prof. Mitchell insists that the dwellers are not lower in mental condition than those who live in the closes and alleys of the Canongate and Cowgate of Edinburgh. These in the city "are persons not only uncultured, but to a large extent incapable of culture; on the other hand, the people found living in these black houses are not the dregs of a community, but a whole community." One wonderful peculiarity in the black houses is that the turf roof does not throw the rain water clear of the walls, but is so constructed as to allow the water to fall exactly on the walls. Can this be stupidity? The author asserts that it is not; that it is not from a want of mind or want of knowledge. The people know perfectly well the effects and advantages of making a roof throw rain beyond a wall. Here we cannot agree with Prof. Mitchell, but must think that human degradation has been carried so far as to blunt their perceptive faculties.

One quite terrible chapter, treated, however, in a philosophical spirit, is the one describing cave life, as it may be seen in Sootland in Wick Bay. The scene is revolting. Man and wife, children — boys and girls—were found almost in a state of nudity, without a single feeling of shame. There were hardly any distinctions of sex. A woman mixed oatmeal and water in a tin dish, spreading out the cake on a flat stone, and toasting it before a turf fire. There were neither tables, chairs, nor stools; the people sat on stones. The cave-dwellers were tinkers, ostensibly, but they made horn spoons, told fortunes, clipped horses, and begged and stole. They were not gypsies. Light and red hair, blue eyes, and freckled skins were common. They were slightly built, and did not look vigorous. Their heads and faces were unusually bad in form, their expression resembling those who had been convicted of petty crimes. Broken noses and scars were common. Their origin was uncertain. They were Scotch and Irish, the dregs of a race, "persons who had dropped out of the line of march," but not worse, the author thinks, than the degraded class found in Edinburgh or Glasgow. Suppose we were to describe a horde of Bushmen as having no sense of shame, with the feeblest appreciation of virtue or chastity, ignoring truth, indifferent to honor, unable to read or write, without a glimmer of belief, utterly ignorant of God, this portrayal would be accepted. Its exact application might be found for these cave-dwellers, with but one exception. The Bushman could not work tin as these men did. But would not a flint arrow, at least for the fashioning of it, be equal to the skill of a caveman just described when he beat out a pan? The Bushman might be taught to make the tin pan, but it is quite uncertain whether the Scotch cavemen could ever fashion the arrow-head. The past amid the present is further shown by the existence of the tinder-box, and of the crusie—the oil-lamp of old Scotland. Thirty or forty years ago there were millions of crusies in Scotland, and now they are so rare as to find a place in collections. In Shetland, the bismar, a crude wooden steelyard, is still in use, the only difference from the other steelyards being that it has a fixed weight and movable fulcrum, instead of a fixed fulcrum and movable weight. Sinking stones used in the Shetlands by fishermen are discussed—simple weights which carried the hook to the bottom for deep sea or river fishing. There is positive survival in a great many fishing implements. In Norway, as in the Shetland Islands, the same methods of sinking lines or nets are employed as must have been in vogue thousands of years ago. It would have been exceedingly interesting if Prof. Mitchell had told us of having found any gorge-stones—for catching fish—for the same implements made by prehistoric man in France served our Indians but twenty years ago on the shores of Lake Superior.

JOHN GOULD, F.R.S.

THE grave has recently closed over the remains of a very remarkable man, and although the annals of science, we are proud to think, afford many instances of indomitable energy and unceasing perseverance rewarded, they have no greater record of success than is to be found in the life of John Gould. No one can regard the series of works written and illustrated by him without acknowledging that they are a monument of human energy, and the story of his life makes the fulfillment of these large enterprises the more interesting. In the character of the man we must look for the secret of his success, because it is well known that he possessed neither the advantages of wealth nor education at the commencement of his career, and yet he has left behind him a series of works the like of which will probably never be seen again; and this because it is rare to find the qualities of a naturalist, an artist, and a man of business combined in one and the same person. John Gould was all these in an eminent degree; he knew the characters of birds as well as any man living, and although it has been often said that he made too many species—and latterly it has been the fashion with certain writers to sink a good many of them—yet the monographer, traveling over the ground again, generally finds that the critic, and not Gould himself, was at fault. As an artist, he possessed talent combined with the greatest taste, and this, added to the knowledge of botany, acquired in his early days, enabled him to give to the world the most beautiful series of pictures of animal life which have yet been produced. Certain special works, where the pencils of Wolf or Keulemans have been employed, may vie with those of Gould, but taken in a collective sense, his splendid folios, full of colored plates, are as yet without a rival. That he was a good man of business the fact that his writings were not only self-supporting, but further realized him a considerable fortune, is the best proof. Though in outward seeming he was stern and even somewhat brusque in manner, those who knew him well can vouch for the goodness of his heart, and can tell of many an act of kindness and charity, concealed from the world under a bluff exterior, and no one ever heard him speak unkindly of any of his contemporaries. Straightforwardness was one of his especial characteristics, as well as an exact manner of doing business, paying for everything the moment the work was done; and this probably accounts for the way in which his artists, lithographers, and colorers worked for him for long periods of years.

Mr. Gould at his death was in his seventy-seventh year, having been born in September, 1804. He was a native of Lyme, in Dorsetshire, but when quite an infant his parents moved to the neighborhood of Guildford. When he was fourteen years of age his father was appointed foreman in the Royal Gardens at Windsor, under Mr. J. T. Aiton, and here the lad had a grand opportunity of studying British birds in a state of nature; in his collection are still to be seen two magpies shot by himself and stuffed at the age of fourteen, which are even now most creditable specimens of taxidermy, and foreshadowed the excellence which he afterward attained to in that art. Till the year 1827, when he came to London, he was still employed in active gardening, having left Windsor for a post at Sir William Ingleby's, at Ripley Castle, in Yorkshire. Immediately after coming to town he was appointed curator to the Zoological Society's Museum, at that time in its infancy, and he enjoyed the intimate friendship of Mr. N. A. Vigors, then one of the leading English naturalists, and through him John Gould received his first opportunity of appearing as an author. So rare were Himalayan birds in those days that a small collection was thought worthy of description by Mr. Vigors in the Proceedings of the Zoological Society, and the figuring of these specimens was commenced by Mr. Gould under the title of "A Century of Birds from the Himalayan Mountains." By this time, however, an event had taken place which had an influence on the whole of his later life, viz., his marriage with Miss Coxen, the daughter of Mr. Nicholas Coxen, of Kent. Besides her other accomplishments, Mrs. Gould was an admirable draughtswoman, and, from her husband's sketches, she transferred to stone the figures of the above-named work. Its success was so great that in 1832 the "Birds of Europe" was commenced, and finished in five large folio volumes in 1837, while simultaneously, in 1834, he issued a Monograph of the Rhamphastidæ or family of Toucans, and in 1838 a Monograph of the Trogonidæ or family of Trogons. To the last he maintained his love for these birds, and one of his most recently finished works was a second edition of the last-mentioned Monograph. It is a curious fact that when John Gould proposed to publish his first work, he applied to several of the leading firms in London, and not one of them would undertake to bring it out, so that it was only with reluctance that he began to issue the work on his own account. Besides these larger publications, he had described the birds collected during the voyage of the Beagle by his friend, Mr. Darwin, and had contributed papers on other subjects to the Zoological Society's publications.

We now come to what we consider the most striking incident in Mr. Gould's life, one unsurpassed in its effects in the annals of ornithology. Beyond a few scattered descriptions by some of the older authors and an account of the Australian birds in the museum of the Linnæan Society, by Messrs. Vigors and Horsfield, the birds of Australasia were very little known at the date we speak of. Accompanied therefore by his devoted wife, Mr. Gould proceeded in 1838 to study Australian birds in their own home, and he personally explored Tasmania, the islands in Bass's Straits, South Australia, and New South Wales, traveling 400 miles into the interior of the latter country. This voyage, especially undertaken for the purpose of obtaining an exact knowledge of Australian birds, must ever be reckoned as a distinct scientific achievement, and the accounts of the habits of some of the more remarkable species, such as the mound-building Megapodes and the Bower birds, were quite triumphs in the way of field ornithology. Nests and eggs were collected as well as an excellent series of skins, both of mammals and birds, and here Mr. Gould's beautiful method of preparation was especially noticeable; some of his specimens, skinned more than thirty years ago, are as neat in appearance and as fresh as the day they were prepared. Returning in 1840, after two years' absence, he commenced the great work on the "Birds of Australia," which makes seven folio volumes and occupied seven years in its production, being completed in 1848. One of the features of this work is the great increase in our knowledge of the range and habits of petrels and other sea birds, to which the author paid great attention during his travels.

Within a year of Mr. Gould's return from his adventurous voyage he had the misfortune to lose his wife, and for some time he was completely overwhelmed by his bereavement. His collectors in Australia, too, about the same period, lost their lives; one of them, Mr. Gilbert, was killed during Dr. Leichhardt's expedition overland from Moreton Bay to Port Essington, and Mr. Drummond, while collecting in Western Australia, was also murdered by natives, and a third collector was killed by the explosion of a gun on one of the islands of Bass's Straits. It speaks volumes, however, for the zeal and energy with which Mr. Gould had prosecuted his researches in the Australian continent that very few birds, sufficient only to form a supplement in a single folio volume, have been discovered since he left the field of his labors in that quarter of the globe.

Another landmark in the career of this great ornithologist was his publication of his Monograph of the Trochilidæ, or Family of Humming Birds. These lovely little birds had been for a long time favorites with Mr. Gould, who gradually began to amass that fine collection which has been the admiration of naturalists for so many years. Taking advantage of the Great Exhibition of 1851, he obtained permission from the Zoological Society to erect at his own cost a large building in their gardens in the Regent's Park, where the collection was open to the public at a charge of sixpence per head. A considerable sum was realized by this exhibition, and a large number of subscribers to his monograph was obtained, including nearly all the royal families of Europe. Though sketched by Mr. Gould himself (for even to the last days of his life he executed the designs for all his plates), the majority of the humming birds were placed on stone by Mr. Richter, who also did the same for Mr. Gould's next work, "The Birds of Asia." We cannot but regard this as one of the most valuable of all the works done by

the author, for, notwithstanding the fact that it is left unfinished at his death, it contains a large number of plates of species not elsewhere figured. The "Mammals of Australia," produced simultaneously with the last-mentioned work, deserved, in Mr. Gould's own opinion, more credit for its issue than perhaps any work he had done, because it touched upon a branch of zoology of which he never pretended to have a very exact knowledge. So large, however, had been his collections of mammalia during his sojourn in Australia that some account of them seemed to be demanded, and he therefore published his large folio work; but the pecuniary results were less satisfactory than with any of his ornithological productions. His typical specimens of the Australian mammalia are in the national collection. No sooner were the humming birds finished than his active brain conceived a new idea, to illustrate becomingly the birds of his native land, and he commenced the publication of the "Birds of Great Britain." Opinions may differ as to the merit of Mr. Gould's other works; volumes less ponderous than the folios which he adopted for the better figuring of the objects of the natural size may take their place with the student; but no work of greater beauty will be produced than that on which John Gould, returning in his later life to his first love, bestowed the fullness of his energy and the acme of his artistic talent. The care bestowed on the plates of this work was remarkable, the aim of the author being to produce a picture of the birds as they appeared in their natural haunts, and especial pains were bestowed on the young, particularly those of the wading-birds and natatores. In this fine work most of the drawings were developed and placed on stone by Mr. W. Hart, who also executed all the plates of the later works.

In 1865 Mr. Gould republished his letterpress of the big work in an octavo form, under the title of "A Hand-book to the Birds of Australia," but with all the additional species inserted in their proper families; these two volumes are therefore of great use to the student. After the completion of his work on "British Birds," Mr. Gould devoted himself to the continuation of the "Birds of Asia" and the Supplement to the "Birds of Australia," until in 1875 he commenced a work on the "Birds of New Guinea," which was to contain also descriptions of any new species to be discovered in Australia or any part of the Australian region. Of the last-named work eleven parts have appeared, and it was left unfinished at his death, as well as the following works: A "Monograph of the Pittidæ or Ant-Thrushes of the Old World" (one part published), the Supplement to the "Monograph of the Humming Birds" (two parts published), and the "Birds of Asia."

The above list enumerates, we believe, nearly all the works published by Mr. Gould with the exception of the "Icones Avium," issued about 1838, and containing supplementary plates to his previous volumes, with descriptions of new species, and the "Monograph of the Odontophorhinæ or Partridges of America." In addition to the folio volumes he was also in the habit of publishing the introductions to his larger works in an octavo form.

Many of the above details of Mr. Gould's life are taken from "Men of Eminence," aided by the personal recollections of the writer, who was for many years an intimate friend of the deceased, and knew him first as a successful trout-catcher on the Thames, for his prowess in throwing the fly was scarcely second to his skill as an artist. Were he to write an epitaph of John Gould he would do so in the words which Mr. Gould himself was fond of quoting: "Here lies John Gould, the Bird-Man." The latter words were used by an old and intimate friend in introducing Mr. Gould to another relative. We may hope that the Government, according to the well-known wishes of the deceased naturalist, will allow no false motives of economy to interfere with the purchase of Mr. Gould's collection of birds for the British Museum, and that the disgraceful spectacle of his Australian collection (unrivaled to this day, and offered to the nation for the small sum of £1,000) being allowed to leave the country, may not be repeated.—*Nature.*

BEHRING STRAIT.*

On the 3d of September we sailed from Chamisso Harbor for Behring Strait, arriving off East Cape of Asia about 6 A.M. on the 5th. Broken ice intervened between us and the shore, and the bight southward from the cape was packed full of ice. We could not approach nearer to the shore than four miles.

The wind was fresh, but the opportunity seemed tolerably favorable, and I concluded to attempt making the hydrothermal section across Behring Strait at once, rather than risk the chance of a more favorable opportunity with its possible long delays. We therefore proceeded across the strait at its narrowest part, taking temperatures at short intervals on the surface and soundings with serial five-fathom temperatures every four miles, as nearly as we could determine at the time.

The shallow depth of water facilitated our work very much, as we were able to bring up several gallons of water in the bivalve water buckets from any depth in a few seconds, and test it with an unprotected thermometer, giving us much more accurate results than the Casella thermometers are capable of. We found the wind growing more and more severe, and were obliged to reef down during the latter part of the day, but succeeded in getting our last serial sounding, completing the section at a time when we should at any rate have had to cease work, so heavy was the sea produced by the wind against the tide. Finally, we were very glad to run for shelter to Port Clarence, which we reached the following morning quite early.

The diagrams† appended to this report will show the details of the work, and I may say here that the general conclusion reached from these, with previous and subsequent observations in the strait, was as follows: The water is warmest toward the American side, and cools gradually toward the Asiatic side. The highest temperature is 48° F. and the lowest about 36° F. The uniform succession of the vertical curves, representing degrees of temperature, is somewhat interfered with by an eddy around the Diomede Islets in the middle of the strait, but is otherwise very regular.

The uniformity of the temperatures from top to bottom does away with the idea of a sub-surface current from the Arctic Ocean, carrying cold water southward, a result I had expected, and confirmatory of my suspicions expressed in the Appendix to the Coast Pilot of Alaska, and of Onatzevich's observations on the Kamchatka coast.

Our current observations showed another conclusion to be probable, though a more thorough investigation will be required to place it beyond question, namely, that the northerly current through the strait and along the Arctic Ocean is chiefly dependent on the tide for its force and direction, and on the warming of the shallow waters of Norton Sound and the "Yukon" and vicinity, for its high temperature, which is greater than any of the Behring Sea water south of St. Lawrence Island. This would agree with the observations of explorers along the Siberian coasts and elsewhere, where large bodies of comparatively warm water, derived from large rivers, are poured out over shallow areas of a cold sea basin.

The direction of the current in the strait, when we were lying near the Diomedes, was reversed by the tide, and the vessel tailed in opposite directions during flood and ebb. The rate varied with the strength of the tide, and during our stay did not exceed three knots. The directions agreed with the trend of the land on either side of Cape Prince of Wales (along which the tide runs and would naturally gather its greatest velocity) and, as a consequence, diagonally across the strait.

Early in the morning of the 10th of September we arrived at the Diomedes, and were most fortunate, notwithstanding a very strong breeze was blowing, to be able to make a lee under the end of the Big Diomede, and a landing on the snow in a small gully, where observations could be taken. Had the wind varied half a point from its direction this could not have been done, and weeks might have passed without an opportunity.

These islands are granite domes, rising abruptly from the water, and their sides rendered perpendicular by the action of the sea. The water is bold, too; there are no beaches. The weather has acted on the surface of the top of the islands so as to make a sort of broken table-land, the drainage from which has cut a few gullies in the granite bluffs. By digging into the rubbish and massing it below, the natives have obtained spaces sufficiently level to hold a few huts. There are two villages, one on each island. Fairway Rock, at no great distance, is uninhabited and almost inaccessible. Near our station was one hut—empty—and by climbing up the gully, by steps laboriously excavated in the crumbling granite, the natives were able to go over the top of the island to the village on the other side.

Millions of birds afford a large item of subsistence, and seal, and later in the season some walrus, are taken by these natives, who act as middle men in trading between Asia and America. A short but satisfactory set, each, of time, latitude, dip, intensity, and azimuth, was obtained, with angles determining the position of the adjacent island and the prominent features of the mainland on either side.

One of the most important results of the occupation of this station was the determination of the fact that the boundary line, as defined by the treaty, does pass between the two islands without touching either, as was assumed in that document, but which had been put in doubt by certain erroneous charts of the vicinity.

I may say that the decreasing easterly variation which we pointed out in 1873 was extremely marked in the northern stations occupied, some of the results showing five or six degrees less variation than is indicated on the latest charts. A thorough explication of the results must, of course, await the final revision of the computations.

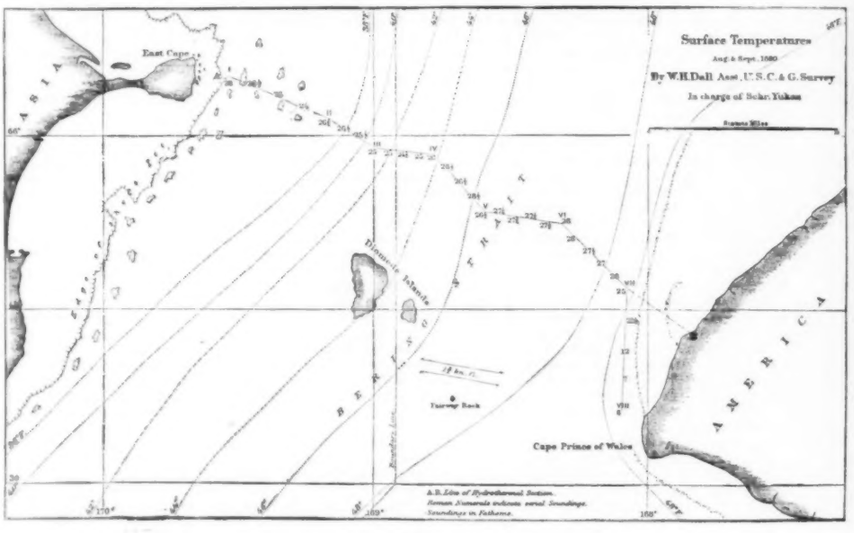


CHART OF BEHRING STRAIT.

HIDDENITE, AN EMERALD-GREEN VARIETY OF SPODUMENE.

By J. LAWRENCE SMITH, of Louisville, Ky.

THE new variety of spodumene described in this paper was discovered about five years since on the farm of Mr. J. W. Warren, in Alexander County, North Carolina. Shortly after its discovery some crystals came into the hands of Mr. Stephenson, of Statesville, the best of which he sent to Mr. N. Spang, of Pittsburg. Subsequently he showed others of them to Mr. W. E. Hidden, a very enterprising collector of the minerals of this region, and from Mr. H. I obtained all the specimens examined, as well as my information in regard to their mode of occurrence. The crystals were found very sparingly, and loose in the soil, but Mr. Hidden having leased the locality and carried on a systematic exploration, has discovered the mineral *in situ*, and obtained many fine crystals.

Up to the time when my attention was called to the mineral it was considered *Diopside*, a reasonable conclusion considering the imperfect character of the crystals that had been found. A blowpipe test, and a determination of its specific gravity showed me that it was *not diopside*, but a new variety of spodumene.

Mode of Occurrence.—In the absence of any drift formation in this region, it is evident that all the minerals found here detached and loose in the soil—as most of them are—were furnished by the rocks beneath. The soil has been formed by the decomposition of these rocks, and surface washings have caused only small displacement of the mineral from its original locality. The rocks are metamorphic, and are mostly gneiss and mica schist.

The vein bearing the spodumene crystals runs almost due east and west across the bedding, and dips at an angle of 70°. It is only a few inches wide and two feet in lateral extension, being in fact a kind of chimney. There are probably other similar veins in the vicinity, but it is only in this one that the crystals have yet been found. The walls of this contracted vein contain crystals of quartz, mica, rutile, *beryl*, and orthoclase. The beryls are *very fine*, and may yet be found sufficiently colored to be valuable as gems. The vein does not come to the surface, but commences about eight feet below it, as a narrow seam of hard kaolin, and in this kaolin lies the spodumene; the vein so far as yet explored having undergone alteration. One end of the crystals is almost invariably broken; but they are sometimes embedded in quartz crystals and are perfect in form; others occur attached to the sides of the quartz. The vein has been worked to a depth of twenty-three feet, without any material change in its character.

Color.—The mineral, which is *always transparent*, ranges in color from colorless (very rare) to *a deep emerald green*; sometimes the entire fragment has a uniform green color, but generally it is more intense at one of the extremities.

Crystallization.—The crystals are very frequently twins, rarely *fourlings*. They are often terminated at one extremity, but the planes are dull and curved, so that good measurements cannot be made. The crystal which is supposed to be a fourling has two sharp projecting edges in the termination, crossing each other. The largest crystal yet found is two and a quarter inches in length, but very thin; the average size is about half an inch long by three-sixteenths in width.

Professor E. S. Dana has kindly furnished me with additional observations, made on some imperfect crystals, which I add here. "The crystals occur in slender prismatic forms, showing in the prismatic zone the two pinacoid planes; in this zone the crystals are deeply striated, and are flattened in the direction of the inclined lateral axis. The terminal planes are uniformly rough and uneven, so much so that no satisfactory determination of their symbols can be made; they often form an edge, as the continuation of the front prismatic edge, and this is rounded over the whole top of the crystal. Some of the crystals are twins with the orthopinacoid as the composition face. An interesting feature of the crystals is the occurrence of *depressions* in the prismatic planes, both the natural planes and those due to cleavage. These figures are shaped something like a sharp wedge; they are inclined at a small angle to the front prismatic edge and in an inverted position to that behind. In the twin crystals, however, they point upward both in the front and behind, in consequence of the inverted position of the other half of the crystal. Great numbers of these figures are sometimes seen, occasionally very minute and much crowded together. The prismatic cleavage is remarkably perfect, yielding surfaces of the highest luster."

The hardness across the crystal is equal to that of the emerald and on the prismatic faces 7. The specific gravity, as taken from various good specimens, averaged 3·189.

Its behavior before the blowpipe is the same as that of other forms of spodumene. When heated to redness in the flame, but not fused, it loses its color, but on cooling regains it—a reaction analogous to that afforded by the emerald. I have as yet in vain sought for the cause of the color. I have employed all the necessary care in examining for chromium, but have found no indication of its presence. In an examination made for vanadium, the result of an experiment with two grammes of green material was lost. This behavior in the flame—losing its color and recovering it again on cooling—belongs as well to chromium as to vanadium.

Composition.—A careful analysis yielded me the following results:

Silica	64·35
Alumina	28·10
Ferric oxide	0·25
Lithia	7·05
Soda	0·50
Loss by heat	0·15
	100·40

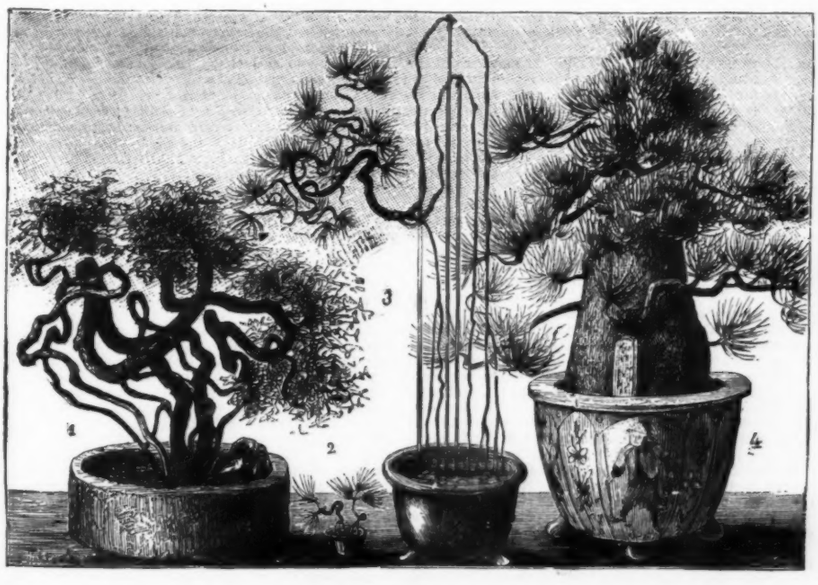
The specimen analyzed was of the paler variety. There is a trace of potash in the soda.

It is one of the most beautiful varieties of spodumene I have ever seen, and I think its beautiful color entitles it to a distinct name. I therefore propose the name of *Hiddenite*, after the indefatigable mineral explorer who has directed our attention to it.—*Amer. Jour. of Science.*

* Extract from a recent report to C. P. Patterson, Superintendent Coast Survey, by W. H. Dall, assistant in charge of schooner Yukon.

† The diagram of hydrothermal section, showing surface temperatures and depth, is the only one that could be engraved in time for this issue.

REMARKABLE BANYAN TREE GROWING AMONG THE RUINS OF A CONVENT AT BASSIEN, INDIA.



JAPANESE TREES DEFORMED BY CULTURE.

1. *Rhynchospermum japonicum*, dwarfed and misshapen. 2. Young *Pinus densiflora*, dwarfed. 3. The same species misshapen by treatment (1/6 nat. size). 4. Another specimen of the same species of pine, aged one hundred years.

THE BANYAN TREE.

TRAVELERS tell us that the colossal wild fig trees are among the most grateful presents of nature to hot countries; the shade of their magnificent head refreshing the wayfarer when he reposes under their incredibly wide-spreading branches and dark-green shining foliage. The genus *Ficus*, to which these trees belong, is that which most conduces to the peculiarities of a tropical scene. In India, two of the species have historical celebrity. Of these, the Banyan-tree, so remarkable for its vast rooting branches, is the *Ficus Indica;* the Pippul, or sacred fig of the same country, readily known by its rootless branches and heart-shaped leaves with long, attenuated points, is *Ficus religiosa*.

The former of these, the Banyan, is not only remarkable for its growth, but also for its longevity. The fruit is red, and not much larger than a pea, and the seeds are minute and covered with a hard testa which protects them from the digestive organs of the birds which seek the fig as food. The birds plant the seeds by means of their excreta in crevices of stones or buildings, or on trees, and with the necessary moisture the seeds germinate in these places, sending their roots into and widening the chinks, or down the moist bark of the tree on which the seed has been dropped, and the plant grows rapidly into a broad, spreading, although not very lofty tree, whose horizontal branches send down roots as slender fibers until they reach the earth, when the growth is reversed and the depending rootlet becomes an ascending trunk, equaling or even surpassing the parent stem. A famous banyan stood on the banks of the Nerbudda which could shelter 7,000 men, and others cover more than 13 acres. They are frequently found near temples and on the mounds where the Hindoo widows have performed suttee, as the birds are attracted to these places. They are always to be met with among ruins in abandoned places, and if man is not present to arrest their growth, they speedily complete the work of destruction of these monuments of the past. Admiral Paris, in a visit that he paid to the deserted cities of Diu and Bassien, India, witnessed many examples of the destructive force exerted by these trees on the buildings there. The accompanying engraving, which we take from *La Nature*, represents one of these remarkable banyans which the Admiral observed growing within the ruins of a convent at Bassien, to the north of Bombay. In his journal Admiral Paris says of the banyan: At first weak, and in size a mere bud, it introduces itself into the crevices of the wall, follows a tortuous course therein, pierces it, and comes out on the other side, and produces branches and leaves. Gradually it increases in size, disjoints the stones, which, although they flatten it, finally give way. If, on the one hand, it destroys and topples over the walls, on the other it succeeds in interlacing portions of them in a network which keeps them together better than the best cements. I saw one remarkable example whose branches held in the air a portion of a wall of about 5 feet by 2, and about 1 foot in thickness. Each stone was yet in its place; but separated from its neighbor by the swelling of the branches, and this mass was supported above the ruins of the remainder of the wall.

DWARF AND MONSTROUS TREES IN CHINA AND JAPAN.

THE gardeners of the extreme East, notably those of Japan, are proverbially skillful, and this fact has been recognized by all who have traveled among them. While it is well known that they are well versed in plant culture, it is not so generally known, perhaps, that they possess a knowledge of processes whereby they are able to artificially render abortive the growth of plants, causing them to assume abnormal forms and thus take on those curious and fantastic appearances that are so characteristic of Japanese and Chinese art. Mr. E. A. Carrière, the editor of the *Revue Horticole*, has published on this little-known subject some interesting notes, which we borrow in part for the present article. The processes in general which are used by the Japanese to restrict certain plants to more or less reduced dimensions are called "nanism." In these processes they certainly excel, and they may be said to have made an art of them. This art may be divided into two categories, one of which consists in so dwarfing the plant that its natural habit is preserved, and the other in modifying its form during the dwarfing process. For want of a more precise term we may call the methods in general comprehended in the latter category, collectively, "Monstrufacture," since they consist not only in dwarfing the plants, but also in giving them, much in advance of maturity, the aspect of the old, decrepit, and misshapen individuals of the same species which have grown in a state of nature. But it may be asked how the Japanese arrive at these curious results. Of this, Mr. Carrière endeavors to give some explanation by the aid of hypotheses. It is probable that when the Japanese wish to prevent the growth of a plant they select species, and probably varieties, which lend themselves readily to the process, and whose nature allows of their being kept in a dwarfed state. Then the branches of these are variously bent, and kept in position by ligatures in order to make them assume a definite form. It may be conjectured, too, that the plants are deprived of nourishment, or are given merely enough of it to barely support life. This fact explains how it is that we often see plants a century or more old which are very small and can live in pots of relatively small dimensions. The trunk sometimes entirely fills these pots, as in the specimen represented in the accompanying engraving at No. 4. In addition to all this, it must be remembered that the climate of Japan is remarkably adapted to a course of treatment so contrary to the normal development of the plant; for in hot, arid countries it is very doubtful whether these trees could endure this abnormal culture.

Of all plants, the conifers appear to be the ones on which the Japanese especially exercise their art, and it is principally the pines that they submit to the dwarfing and monster-making operations. The accompanying figures show some very remarkable examples of the results obtained in this way. In No. 3 the greatly reduced trunk is placed at some height in the air, and the roots are, for the greater part of their length, supported on a frame. The plant shown in this figure was about fifty years old and was no more than twenty-eight inches in height. The plant figured No. 1 was about thirty-five years old. The young pine, No. 2, was a specimen shown at the Paris Exhibition of 1878. It was, it appears, about ten years of age. The small tree figured No. 4 was about one hundred years old. It was about four feet high, and the pot in which it was contained was twenty inches in diameter. The Chinese, likewise, excel in this art of dwarfing trees, and do not confine their operations to ornamental plants, but extend them to fruit trees as well.

CULTIVATION OF CAOUTCHOUC TREES IN INDIA.

IN Mr. Markham's recently published "Peruvian Barks" there is an appendix on the above subject, and from this and other sources the following account has been drawn up by Mr. James Collins:

In January, 1868, a paper appeared in Dr. Seemann's "Journal of Botany," on "The Commercial Kinds of India-rubber or Caoutchouc," by Mr. Collins. This paper was, for the most part, a *résumé* of what had been written on the subject, and also contained the results of personal observations on the preparation and commerce of that article, together with an endeavor to fix the botanical sources of the various varieties.

At the instance of Mr. P. Le Neve Foster and the distinguished botanist and traveler, Dr. Seemann, the author of this article followed up the subject, and the result of his further researches were given in a paper entitled "India-rubber: Its History, Commerce, and Supply," read before the society in December, 1869. The concluding remarks in this paper are as follows:

"There is one subject which I would more especially recommend to the attention not only of those present, but also submit to the attention of her Majesty's Government, that is, the acclimatization of the different species of *Hevea* (and also, incidentally, I would mention the species of *Isonandra*, which yield gutta percha) in such of our own eastern possessions as will be found best suited."

Owing to the prominence thus given, the subject of the introduction into and cultivation of caoutchouc trees in India was not allowed to drop, and through the representations of Mr. Markham, Mr. Collins was commissioned to prepare a report on the subject for the Secretary of State for India. This "Report on Caoutchouc" was published in 1872. The following passage from it may be quoted here:

"The cultivation of economic plants, and the acclimation in localities where the various conditions, which are so many elements of success, are more controllable than in their native habitat, has a very important bearing on the commerce of a country, and becomes the more necessary for the sustentation and improvement of trade and manufactures, as the march of civilization and colonization or the recklessness of native collectors reduces the area and number of spontaneous forest products. It may be taken as an axiom beyond all controversion that we cannot long rely on the spontaneous products of the forests, but that recourse must be had, sooner or later, to conservation, cultivation, and acclimatization in order to keep up supplies of all necessary vegetable products."

The recommendations were that the (1) *Heveas*, yielding Para caoutchouc; (2) the *Castilloas*, Central American caoutchouc; (3) the *Vaheas*, Madagascar caoutchouc; (4) the *Landolphias*, African caoutchouc; and (5) the *Urceola elastica*, Borneo caoutchouc, should be introduced into India; and that the cultivation of the indigenous *Ficus elastica* should be forthwith attended to. Of the various plants mentioned, the relative values of their products were taken into consideration, the *Heveas* and *Castilloas* being specially mentioned.

These views were adopted and steps taken to carry them into effect. Meanwhile, Mr. Collins sent out full instructions to a correspondent on the Amazons, and was fortunate enough to obtain seeds of the *Hevea braziliensis*, and plants raised from these seeds at Kew were taken by Dr. King to India in 1873. Thus India obtained her first Para caoutchouc plants. A still larger supply was collected and brought home by Mr. Wickham in 1876.

Still, not only were seeds and plants to be obtained, but, as was pointed out, there were many questions to be cleared up. Further information was wanted on the physical and climatic conditions under which the trees best flourished, and the best methods of preparing the caoutchouc, etc., and for this purpose observations on the spot were absolutely necessary. In the selection of a proper person, Mr. Markham was so fortunate as to secure the services of Mr. Robert Cross, whose previous travels in search of cinchona plants, and his knowledge of the country and languages, eminently fitted him for the task.

Mr. Cross left England for Panama Isthmus in May, 1875, and first searched for Castilloa plants, yielding the well-known Central American caoutchouc. The species which he first met with proved to be the *Castilloa markhamiana*, so named by Mr. Collins in honor of Mr. Markham. This species grows to a height of 160 to 180 feet, with a diameter of about 5 feet, and a full-grown tree yields about 100 lb. of caoutchouc. The wood is soft and spongy, and rapidly decays. Some caoutchouc prepared from these trees by Mr. Cross was reported to be superior in quality to that yielded by the historic *Castilloa elastica*. The range, too, of these trees was so wide that in certain districts part of the year is dry. Of the plants collected, 134 flourished at Kew, and of these a goodly supply was forwarded to India in 1876.

Mr. Cross again left England in 1876, this time to procure seeds and plants of the Ceará caoutchouc tree, and further supplies of the Heveas. In both efforts he was successful, resulting in the establishment of 1,000 plants of *Hevea braziliensis* and a goodly number of Ceará plants, all in fine condition at Kew.

The tree yielding Ceará caoutchouc till this time was unknown, and to Mr. Cross is due the honor of clearing up its origin. In trying to get up young plants he could not move them, till digging round the roots he found them furnished with tubers of the size and shape of kidney potatoes, and, from materials brought home, the plant is recognized as *Manihot glaziovii*, a near relative of the tapioca plant. Quotations from Mr. Cross's report on this journey have already been published in this *Journal* (July 12, 1878), and the report is full of practical information of the utmost cultural value.

Mr. Markham sent the bulk of these plants to Ceylon, from whence, as he says, they can be distributed to suitable spots in India as soon as the government are less lukewarm on the subject and fully recognize the importance of the scheme. In Ceylon the Heveas grow remarkably well, and some trees have reached a height of nearly 30 feet, with a girth of 14 inches. The Castilloas also do equally as well. Later information from Ceylon shows that private planters are taking up the question, and Dr. Trimen, the newly-appointed director of the Peradeniya Gardens, has published for their use a series of instructive notes on the cultivation, based on the reports of Messrs. Collins and Cross.

As to Madagascar caoutchouc plants, very little information is to hand. Mr. Markham mentions (*Journal of the Society of Arts*, April, 1876) that seeds of *Vahea* have been sent to India.

With regard to African varieties, Dr. Kirk has displayed much interest, and has procured many plants of the Landolphias. Mr. T. Christy has procured several plants of *Landolphia florida* and *Urostigma vogelii*, as well as plants of an apparently new kind from East Africa, yielding an excellent quality of caoutchouc, and some fine and healthy examples of these are now in that gentleman's nursery.

Thus of the various introduced kinds it is pointed out that the Heveas produced the choicest and best caoutchouc, and are well fitted for the moist zones of India. Castilloas will grow over the largest area, and new homes can be found for them in the Western Ghâts. Ceará kind thrives on drier ground, and may find a fitting home in the hot, dry plains of India.

In the efforts to introduce these exotics into India, the primary recommendation to cultivate and conserve the indigenous *Ficus elastica*, yielding Assam caoutchouc, has not been lost sight of. The first attempts, commenced in 1873, were comparative failures; but since that date the superintendence has been placed under Mr. Gustav Mann, and under his able management the experiment begins now to assume some importance, and, roughly speaking, there are now 1,000 acres in Assam under this cultivation, and the trees are making vigorous and excellent progress.

One other plant deserves notice—a Burmese one—as likely to prove of great utility as a source of caoutchouc. It is the *Chavannesia esculenta*. This plant, of a climbing habit, was always looked upon as a pest by the forest department of British Burma, and every means taken for its extirpation, as it injured the teak trees. Mr. Strettell, one of the officers, however, discovered that it contained caoutchouc, and seems to have proved conclusively that it will repay cultivation. If this turns out to be the case, it will only be another exemplification of the fact that "a weed is an unutilized plant."

Thus, although but yet in its infancy, the subject of the acclimatization and conservation of caoutchouc-yielding trees has arrived at such a stage that its practicability is placed beyond all doubt, and the society may well congratulate themselves that the warm support accorded to the idea when first brought before them has proved an important factor in the present state of affairs. Nor must the action of Kew be forgotten. The valuable aid and support given to Mr. Collins by Sir Joseph Hooker, and the great care he has bestowed on seeds and plants sent to that establishment, have been of the utmost practical moment.

As Mr. Markham says: "This, if intelligently and continuously followed up, will thus insure in the future, as the demand increases, a regular and large supply of the best kinds of caoutchouc from British India."—*Jour. Society of Arts.*

PLANT LABELS.

THE Rev. C. Wolley Dod, of Edge Hall, Malpas, writes to the *Gardener's Chronicle*, as follows:

"On going round the herbaceous garden at Kew, it has often occurred to me that the labels are taken up and laid together every time a bed is raked, and afterward replaced by the laborer from memory, the evident transpositions having seemed difficult to explain in any other way. But after the experience of this winter, when nearly all our flat wooden labels are not only out of the ground, but appear to have been shot out, something in the way in which I have seen porcupines at the Zoological Gardens shoot out their loose quills, so as to be at a distance from the plant which they marked, any amount of demoralization in the naming of mixed borders can be easily understood. Hence the subject of labels is not unnaturally attracting a good deal of attention at present.

"It may help those of inventive genius who are going to compete for the prize for the best plant label offered by Mr. G. F. Wilson, through the Society of Arts, if hints are sent by those who have tried different kinds of labels, so as to give the competitors the full benefit of all past experience. I assume that in all mixed collections of plants a large number of labels is necessary. In my garden, which is of moderate size, I label nothing which can be recognized at all times of the year without a label, and yet I have fully 10,000 labels in constant use. Labels should be (1) cheap, (2) durable, (3) indelible, (4) portable, (5) markable with a common lead pencil, (6) not liable to be ejected by frost, or (7) broken by a kick.

"Those who have plenty of hazel trees at hand will find hazel rods, three-quarters of an inch in diameter, cut into lengths of about ten inches, with a horizontal slice cutting into four inches from the upper end, and made by a single cut of a knife, to take the paint for writing, in many ways better and cheaper than the common flat labels. They last three times as long, or more, if the lower end is dipped in creosote. A common laborer with plenty of material, using a pair of pruning shears, and a strong, sharp knife, will easily cut 1,000 in a day, and they possess qualities 4, 5, 6, and 7.

I have, however, invented and adopted another label—clumsy, I admit, and not readily commending itself to others, but far more simple in practice than it sounds in description. It reminds me of the military regulation order explaining the cocking of a musket, or printed directions given for learning to swim. What reads and sounds as if it were difficult and complicated, becomes in practice the simplest thing in the world. Common round bar iron, three-eighths of an inch in diameter, is cut obliquely into lengths of ten inches, and pierced with an eye one-quarter inch from one end, and dipped when redhot into gas tar. For these pegs, which weigh about 4 oz., I pay 50s. per thousand, but think they might be had for less. Then I have flat wooden suspending labels pierced at each end, for which I pay 4s. 6d. per thousand; through the two eyes, 8 inches of pliant wire is passed, for fastening the label to the iron pin. These are, upon the whole, the most satisfactory labels I have yet used. They cost 5s. 6d. per hundred, but the iron pin—nine-tenths of the cost—is indestructible. The label is easily and quickly renewed, and will last, when suspended, for many years. Not one has been ejected from the ground this winter, and if kicked over they are not hurt, and easily set up again. It is true they are heavy to carry about, but I keep a stock of the pins which are weather proof, in various corners, so as to have them handy for all parts of the garden.

"Then the wired labels are just as portable and as easily written on as common flat wooden pegs. My great desideratum is a white paint which will reject the splashing of mud, but retain for ever the writing of a lead pencil. I can get no paint which is perfectly smooth and not sticky when dry, and should be thankful to be told of any. I inclose specimens of what I have described.

"I may add that a heavy plant label is not altogether without its advantages. In the year 1842, when I was a boy at Eton, one of the many jackdaws which built in the college chapel insisted upon having her nest so arranged that she could, while sitting, see out of the turret loophole, which looked toward Windsor Castle. This could only be done by making the foundation on a step of the spiral staircase, nine feet below; and a massive nest, nine feet high, accordingly was built. I made friends with the college clerk, and watched the progress of the nest, and recollect that among the materials, besides there being a box of lucifer matches, garden pegs seemed to be in great request. Three or four years later, when I was at Cambridge, I recollect the present Professor of Botany exhibiting, at a meeting of the Ray Club, a newly devised label for use in the Botanic Garden there. It was a very heavy metal one—the weight, he said, being found necessary to prevent the jackdaws carrying them up for their nests between the roofs of King's College Chapel."

THE CULTIVATION OF CELERY.

PRESIDENT ROBINSON, of Brown University, recently addressed the Providence, R. I., Society for the Encouragement of Domestic Industry on the subject of celery raising. The *Journal* of that city reports the address as follows:

Dr. Robinson remarked that some fifteen years ago he not only had a ruling taste for gardening, but had indulged that taste, and had experimented considerably in the cultivation of celery. His attention had been called to his experiments by the difficulty which he had experienced during the past winter, and indeed for ten winters, in getting first-rate celery in the market. He had been compelled to pay a large price for a very poor quality. He had been told that celery could not be raised hereabouts successfully, but he knew of no reason why it could not. Celery was a wild plant originally, and was found in the marshy districts of England, and also on the other side of the North Sea near the water in ditches. It was discovered by some one that though in its wild state it had an acrid, unpleasant flavor, yet when it was blanched, it had an agreeable taste, was highly palatable and digestible with certain kinds of diet. He did not know how long ago celery was cultivated in England. He doubted that it had even grown wild in this country. There was a discussion in an agricultural journal, as to whether the delicious flavor of canvas-back ducks was not due to their eating wild celery in the New Jersey marshes, but inquiry elicited the information that it was an aromatic plant unlike the celery. He referred to the growing popularity of celery and its use in that delicious dish known as chicken salad. It acts as a quietive on the nerves, but has not a narcotic influence like the lettuce. Celery would be more extensively used if it could be furnished at a lower figure. He had been paying twenty cents for that which would give the cultivator a good profit at six or eight cents.

In this country the English method of cultivation was followed. One of the best treatises on celery was written by a Mr. Roessle, known to the traveling public as the proprietor of the Delavan House in Albany. From the sale of celery he accumulated sufficient money to erect the hotel, and between the years 1854-70 no better celery was found in the world than that served by him. To cultivate celery sow the plant in a bed similar to cabbage plants, or any other vegetable to be transplanted, and sow it in May. In this climate it is impossible to obtain celery in early summer, but only in the autumn. The plants should be ready for the trenches from the 10th to the 20th or 25th of July. Some say that the plant should be transplanted to the surface of the soil in order to become more stocky, the tendency to grow slender being noticed if they remain in the bed. Others say when they have attained the height of six inches, they should be put in the trenches some six inches apart. The gardeners in New Jersey and New York, in the dwarf species, plant on the surface and hill up about it. The trenches are located near ditches and in moist soil. In our climate a trench should be made and no planting on the surface. The depth of the English trench is twelve inches below the soil. As to whether the sides should be perpendicular or wide, upright sides were necessary in our climate as a protection and support to the plant. A trench ten inches in depth ought to suffice for ordinary celery. If one has plenty of land, the depth can be increased to twelve inches and an equal width obtained. It is necessary, if the depth is twelve inches, to remove the poor soil and put in three or four inches of rich compost. Celery is an exceedingly rich feeder, but does not require green manure. It grows rapidly, and should be provided with rich food. If the celery is put out on the 20th of July it has a month to grow, and if it has attained the height of six inches when it is transplanted, in the latter part of September it will have reached a generous height.

In blanching the celery, the English begin at the height of six inches and hill it up at frequent intervals for two weeks. The chief objections to this method are that the leaves spread, the rains wash the soil down on the plant, which is fatal to blanching, and the celery is blotched, backened, and shriveled. Dr. Robinson did no hilling until after the stalk had grown to twelve inches from the surface. Then he gave the plant a good solid hilling up to the branch, or twelve inches of soil. The soil should be carefully prepared, freed from sods, lumps, and gravel, and placed compactly about the plant. In hilling, the precaution should be taken to gather up the stalks separately and bring them closely together. He had used a kind of matting found in furniture stores in keeping the plants together. By the latter part of September, when the plant is ready to be hilled, it ought to have a good solid stock. If the hilling is thus managed the quality will not resemble the spindle-shanked kind known as Boston celery. He had seen celery round, crisp, and easily broken, and as white and clear as pearl. After it has been hilled in September, anywhere from the 20th to the 25th, let it stand three weeks, and in October hill it again, so as to just show the top of the plant. Then let it stand another three weeks, and it will be blanched and ready for the market. If it were to stand three weeks longer its quality would be improved. Many persons had accidentally hit upon a method of blanching celery. Take the wild plant, and after it has been placed in a dark cellar and covered with straw in October, in two or three months it will be found to be blanched. He believed that two hillings were incomparably better than twelve, and it would prevent the washing of the earth upon the plant and the production of a spotted and unsalable quality.

There are two or three ways of keeping celery. If the winters were no colder than that two or three years ago, a covering of straw would be sufficient, but a winter like the past would kill the plant with frost. Some persons favored planting it in the cellar and covering it with sand, but he was not disposed to place any vegetables in his cellar, as it endangered the health of the occupants of a house. One objection to placing it in a barn cellar was the difficulty of reaching it. He suggested the digging of a pit or "potato cellar" in the north side of a sandy hill so as to secure a comparatively uniform temperature. If the sand were solid, there would be no necessity of supports, but if it was

gravelly, they should be employed. Then a roof should be erected of boards, and made water-proof, and there should be a door. The cellar should be dark, and then a load of horse manure should be packed against the entrance. Celery placed in the cellar and covered with sand often comes out green, and loses its delicate flavor. The celery can be taken out every day, and is ready for the market, and is wholly unlike the stuff sold in this market. It will be found that the celery put out the first of May is better than when it is stored in November. Mr. Roessle expended $1,000 in experimenting on celery, and is decidedly in favor of two hillings, and has adopted such a plan in cultivation and blanching as has been described.

As to the soil, Roessle raised celery successfully on an exclusively sandy soil, and any soil that will hold manure and soil around the plant can be used. It can be put in as a second crop, after the harvesting of other vegetables, and it will stay until the frost comes. It is not difficult to cultivate celery after a man has got his hand in.

In reply to several questions, Dr. Robinson said that in packing the celery it should stand up; should say that soil best adapted for peas and potatoes was equally good for celery; think that the roots would be more likely to keep moist were the plants set from six to eight inches apart; the seed should be sown the same as turnips; there was another kind of celery known as celeriac or turnip celery, highly prized by the Germans, who use the bulbs for sauce; seaweed would be a good covering, as celery is fond of saline soil; only one row was necessary in the trench; prefer one good, solid, honest stock to the Boston sprout celery, and the flavor is superior; thought that the plants should be grown in the shade to insure a vigorous growth.

A gentleman formerly residing in Lewis county, in northern New York, where the climate was invariably cold, stated that he had raised excellent celery, and in blanching it he put down stakes and covered them with boards, two feet apart, filling in carefully with earth. He had tried the experiment of leaving the plants out all winter, with excellent results. The profits were enormous, and he had realized from a patch fifteen feet square the sum of $10, and had plenty beside for his family. The celery was covered with snow during the winter, and came simultaneously with the frost which froze the plants solid.

VITALITY OF CARBUNCULAR GERMS.

By M. PASTEUR.

AT a farm near Senlis, cattle which have died of carbuncular fever twelve years ago have been buried at a certain spot in a walled garden. Samples of the soil were lixiviated and concentrated, and guinea pigs inoculated with the matter died quickly with well-marked symptoms of carbuncle. Of seven sheep allowed experimentally to pass a few hours daily on this spot, two died of the same disease in the course of six weeks, while the rest of the flock from which the seven had been taken remained healthy.

NITROGEN. SYMBOL N. COMBINING WEIGHT, 14.

By T. A. POOLEY, B.Sc., F.C.S.

THIS element, which must next engage our attention, is one which is widely distributed, although not to the same extent as the two elements we have already studied. The mere fact that nitrogen constitutes four-fifths by volume of our atmosphere, makes the study of this element of importance. It is also a constituent of the nitrates of potassium and sodium, large beds of which salts are found in some parts of the world; both nitrates and nitrites are frequently met with in well waters, and nitrogen also occurs in coal and some minerals, and it is an important constituent in the tissues and juices of both plants and animals. The name nitrogen signifies niter producer, and was originally given on account of the occurrence of this element in niter; but French chemists have a far more appropriate name in *azote*, which signifies a depriver of life, and refers to the principal property of nitrogen.

Nitrogen can be easily prepared from atmospheric air, which consists of a mechanical mixture of this element with oxygen, by removing the latter by means of some substance possessing a strong affinity for it. Any combustible body will answer for this purpose, but the choice should be made of one that forms a product soluble in water, so that it can be easily removed. Phosphorus is by far the most convenient, although great care must be taken in handling so inflammable a body; to prepare nitrogen from air, all that is required is to burn a little piece of phosphorus placed in a cup under a bell jar, standing over a basin of water; when the phosphorus is lighted it commences to burn, and combines with the oxygen, eventually removing every trace of this element; the product is phosphoric anhydride, which rapidly combines with and dissolves in the water, forming phosphoric acid. The residual gas, which on cooling will be found to occupy only about four-fifths of the original space, will be pure nitrogen. There are other methods of isolating this element, but their description would be beyond the scope of the present articles.

Nitrogen is a colorless, tasteless, and inodorous gas; it has a specific gravity of 0·972, being slightly lighter than air or oxygen; it is most inert, and only combines directly with other elements with the greatest difficulty; it will neither burn nor will it support combustion, and therefore a lighted taper plunged into a jar of this gas is immediately extinguished; it is also inimical to animal life, but at the same time it is not poisonous, as is seen by the fact that we are continually inhaling it with the air we breathe; an animal placed in an atmosphere of pure nitrogen will soon die, but not by poisoning, but rather by suffocation, due to the absence of the gas oxygen, which is absolutely necessary to sustain life. Although nitrogen will not easily combine with oxygen or hydrogen, several compounds formed from these elements are known, the properties of which we shall in due course refer to, but at the present stage it will be more convenient to study the properties of the atmosphere.

The atmosphere which surrounds our globe and extends to a height of about forty miles is not a chemical compound, but simply a mechanical mixture, the principal gases being oxygen and nitrogen. The following are the proportions by volume and weight of these two constituents:

	By volume.	By weight.
Oxygen	21	23
Nitrogen	79	77
	100	100

This proportion is very uniform in all parts of the world and at all altitudes. This has been proved by samples having been drawn from valleys, from the summit of high mountains, from above the center of the Atlantic Ocean, all of which possessed identically the same composition so far as the proportion of oxygen and nitrogen is concerned. The combining number of oxygen being 16, and that of nitrogen being 14, it will be seen that these two elements are not present in air in these proportions nor in any simple multiple of these proportions; this fact alone would show that air is not a chemical compound, but it can also be proved experimentally in several ways. A very simple method is to pass some atmospheric air through water, by which a portion is dissolved; on boiling this water the gases will again separate and will then be found to consist of one part of oxygen to two parts of nitrogen. If air were a chemical compound the gases ought to have dissolved in the proportion of twenty-one to seventy-nine, but as oxygen is far more soluble in water than nitrogen, we find that the dissolved gas contains a larger proportion of the first-named element. The presence of oxygen in the atmosphere is proved by the readiness with which certain substances oxidize when placed in it: thus iron rusts, carbon becomes carbonic acid at a red heat, hydrogen is converted into water, phosphorus into phosphoric acid, and the many phenomena of combustion all point to the presence of oxygen; but by the tests already given in our study of oxygen the presence of this element in air can be easily proved.

In addition to the two main constituents, oxygen and nitrogen, air contains certain other constituents which are nearly always present, but in varying proportions, according to the locality and the surrounding circumstances. The amount of aqueous vapor varies very much, but air is never found absolutely dry; the temperature, the season, and the altitude all influence the proportion of moisture; the higher the temperature is the more aqueous vapor will air retain, and if the temperature be then lowered the moisture will separate in the form of small globules. In our atmosphere these variations of temperature, combined with other influences, cause the different meteorological changes resulting in rain, deposition of dew, fog, and cloud, which are so frequent in this country. The amount of moisture in the atmosphere may be approximately determined by an instrument called the "hygrometer," which consists of two thermometers placed side by side, the bulb of one being covered with a piece of linen always kept saturated with moisture. The evaporation of water is always accompanied by a reduction of temperature, and the wet bulb will, therefore, always show a lower reading than the dry bulb, the difference between the two bulbs varying with the quantity of aqueous vapor in the surrounding atmosphere. The hygrometer is a most useful instrument, and the observations made by means of it are of especial value to the maltster, the success of whose operations depends to a great extent on a proper knowledge of the amount of moisture in the atmosphere.

Another important constituent of the atmosphere is carbonic acid, which is always present, but which varies considerably in amount. In the open country, over the middle of the Atlantic, and on high mountains, the quantity of carbonic acid does not exceed two parts in ten thousand parts of air; but in large cities, in crowded rooms, and in the neighborhood of manufactories, the quantity is sometimes as much as twenty parts in ten thousand. Carbonic acid is an essential constituent, for it is from this gas that plants derive their supply of carbon; animals emit carbonic acid and plants reabsorb it, and thus the economy of nature is preserved. In the atmosphere of breweries carbonic acid is generally abundant, in consequence of the large volume which is given off during fermentation. The presence of carbonic acid in the atmosphere can be proved by exposing a little shallow dish of lime water, which rapidly becomes covered with a white film when carbonic acid is present.

Other constituents of the atmosphere are ammonia and nitric acid, which are nearly always present, but often in very minute proportions; in some places sulphureted hydrogen can also occasionally be detected, but it is not a normal constituent, and is due to accidental circumstances.

The chemical composition of the atmosphere is a matter of some importance to both brewer and maltster, especially as regards the quantity of aqueous vapor; but, in addition to the gaseous constituents, there are bodies to be met with in the atmosphere which work the most disastrous changes on such unstable fluids as wort and beer; we allude to the minute germs and organisms which the researches of Pasteur have proved always float about in the air. In some places these germs are much more plentiful than in others, and their effects are then soon visible in the putrefactive changes which ensue. When the idea of Pasteur—of manufacturing beer in an absolutely pure atmosphere—can be practically realized, we may be able to obtain a product which can be indefinitely preserved, but at the present time every vat and cask of beer is a prey to the attacks of these myriads of atmospheric germs for which there is no chemical test, and whose presence is only discovered by the disastrous effects produced by their agency.

Compounds of Nitrogen with Oxygen.

There are several important bodies resulting from the combination of these two elements in different proportions. These compounds cannot be produced by the direct union of nitrogen with oxygen, but they have been isolated by indirect methods. The series is composed of five bodies, of which the following are the names, symbols, and component parts:

Name.	Symbol.	Composition. N.	O.
Monoxide of Nitrogen....	N_2O	28	16
Dioxide of Nitrogen.....	N_2O_2	28	32
Trioxide of Nitrogen.....	N_2O_3	28	48
Tetroxide of Nitrogen....	N_2O_4	28	64
Pentoxide of Nitrogen ..	N_2O_5	28	80

This series will serve as a text for a few remarks on what is known to chemists as the law of multiple proportions, which is to the following effect: That when one body combines with another in several proportions, the higher proportions are always multiples of the first or lower. Thus it will be seen that twenty-eight parts of nitrogen combine with sixteen parts of oxygen; although there are four other combinations containing more oxygen, the proportion of oxygen is found to be a simple multiple of sixteen. This law holds good through the whole range of chemical compounds; in inorganic chemistry the combinations between two elements are usually few in number, and the series we have just given is one of the most extended; but when we come to study organic chemistry we shall find the combinations between the elements far more numerous, but still the law of multiple proportions always holds good.—*Brewers' Guardian.*

THE CHEMISTRY OF BUILDING MATERIALS.

THE science of chemistry enables us to discover the various elementary substances of which compound bodies are formed, and to separate those substances one from the other so as to find exactly the relative proportions of each in any given compound. To do this the chemist must make himself acquainted with various processes which are constantly going on in nature, and the kind of action that takes place when two or more different elements are brought into close contact.

The separation of a body into its constituent elements is called *Analysis*, and is performed by means of certain liquids called *Reagents*, whose action upon other bodies has been carefully ascertained by exact experiments. The principal of these reagents are sulphuric, hydrosulphuric, nitric, hydrochloric, acetic, and tartaric acids; the alkalies, ammonia, potash, and soda, with some of their salts, as well as various salts of the metals. In addition to these there is the blowpipe, which often enables the chemist to determine the presence of any element by the color it imparts to the flame, and also to reduce many of the compounds of metals to the pure metallic condition.

It is rarely that any elementary substance is found in nature in a pure or uncombined state, all the metals, with only two or three exceptions, existing in the earth in combination with other elements, such as oxygen, sulphur, and phosphorus. This arises from the affinity, or tendency to combine, which all elements possess in a greater or less degree. Take, for example, the metal calcium, which is the chief component of all marbles and limestones; this is never found in a pure state, but always in combination with oxygen, forming the material known as lime; and this compound is generally in combination with either carbon, sulphur, phosphorus, silicon, or some similar element, forming the carbonate, sulphate, phosphate, or silicate of lime. Thus, a piece of white marble is nearly pure carbonate of lime, and consists of the elements calcium, oxygen, and carbon, all of which are said to be *chemically* combined, their union being of such an intimate nature that the distinctive characteristics of each have disappeared and become merged in an entirely new substance. These elements have also combined together in definite proportions well known to the chemist, so that the exact weight of each element in the compound can be at once predicted as soon as it has been ascertained that the substance is carbonate of lime. Thus, pure lime (calcic oxide) always contains forty parts by weight of calcium and sixteen parts of oxygen; carbonic acid, twelve parts of carbon and thirty-two of oxygen; these being combined to form carbonate of lime, give, as its composition, forty of calcium, twelve of carbon, and forty-eight of oxygen. The several numbers, forty, sixteen, and twelve, are the *chemical equivalents*, or as they are sometimes termed, the *atomic weights* of these three elements, and whenever they are found in combination with other elements it is always in some multiple of these numbers.

Elementary substances also combine together to form compounds in a much less intimate degree than what has been just described, and the proportions in which they combine are not definite. This is termed a *mechanical* combination as distinctive from a *chemical* one.

A familiar instance of a *mechanical* mixture exists in atmospheric air, which is composed of three gases capable of being readily separated one from the other, and their proportions varying according to circumstances and localities. Water, on the other hand, is a *chemical* mixture of two gases, which can only be separated by bringing it in close contact with a substance for which one of the gases has a stronger affinity than exists between the two which compose the water, and these gases always combine in exactly similar proportions, so that the quantity of either in any given weight of water is readily found by calculation. Nearly all rocks and minerals are mechanical mixtures of various substances in uncertain proportions, the component substances themselves consisting of elements chemically united. Thus, a piece of dolomite is a mechanical mixture of the carbonates of lime and magnesia, silica, iron, and alumina, in varying proportions, each of which is a chemical compound of two or more elements united in fixed proportions. When, therefore, a chemist finds that a mineral is pure carbonate of lime or carbonate of magnesia, he can determine at once the exact proportions which the several elementary substances bear to each other in that mineral without any further analyses. When, however, it is a mixture of substances like the dolomite, he must separate each from the rest and weigh it before he can determine the proportions of the components.

In the effect of weather upon building materials we have instances of both mechanical and chemical action. Driving rain or running water wears away stone by friction, and carries the particles downward by a mechanical force. When water freezes inside a stone, a great mechanical force is exerted which splits it into fragments. When the atmosphere or water contains acids, their action upon stone is a chemical one, and the particles are dissolved and form a new compound. The same is the case with most of the metals exposed to weather—a chemical union taking place between the metal and the oxygen or sulphur existing in the air, and a coating of a totally different material being formed upon the surface of the metal, by which its strength and utility are often greatly impaired.

Change of temperature produces a mechanical action on most materials, metals being expanded in proportion as the temperature rises, while woods are generally contracted by heat, on account of the moisture therein being evaporated.

Having thus briefly noticed the general principles of chemical science, let us now examine in detail its bearings on the materials in common use for building purposes.

STONES.

Under this head we include building stones, limes, mortars, cements, brick, marble, and all other minerals used in construction (except metals and metallic ores). These vary considerably in hardness as well as composition. Granite, basalt, serpentine, porphyry, and marble are the hardest and most difficult to work, having been subjected to great heat in their formation. The limestones and sandstones form a numerous class, usually known under the definite name of *freestones*, but they vary greatly in hardness, composition, and durability, some of the limestones being too hard to work and only fit for burning into lime, while others are soft enough to be cut with a knife. All these stones consist of mechanical combinations, in greatly varying proportions, of some or all, of the following chemical substances—namely: 1, silica; 2, alumina; 3, lime; 4, magnesia; 5, potash; 6, manganese; 7, iron; which generally exist as oxides, carbonates, or sulphates. Before entering upon the description of stones themselves, it will be necessary to give a brief explanation of the characteristics of the above-named sub-

stances, and the mode in which their presence can be detected in any mineral, the specimen being first reduced to fine powder.

1. Silica, the oxide of an element called silicon, is often found nearly pure in the form of sand, flint, or quartz. It is the hardest of all the constituents of the rocks, and can generally be detected by its property of scratching glass whenever it forms the chief component part of any mineral —such as sandstone. It is also insoluble in the strongest acids, so that when a stone has been treated with these, and a portion remains undissolved and of a gritty character, it may be inferred that the residue is pure silica. When strongly heated, however, with potash or soda, it combines with them and forms a glass, which property enables us to detect its presence by means of the blowpipe. Form a bead of carbonate of soda in a loop of platinum wire by heating it in the flame of a blowpipe—this will be opaque on cooling; but if dipped in a little silica and again strongly heated, a transparent bead will be formed on cooling, which will consist of silicate of soda and be soluble in water.

2. Alumina, the oxide of the metal aluminum, is rarely obtained in a pure state, but generally mixed with other substances in the form of a silicate, as in the various clays. It is found in small proportions in most of the freestones, and nearly pure in the material called emery, and the precious stones ruby, sapphire, and corundum. If a stone is treated with dilute acid the presence of alumina in the solution can generally be detected by means of ammonia, which precipitates it as a white gelatinous substance; but if iron is present, as it generally is, the precipitate will have a brownish tint. If this precipitate is dried and heated in the flame of a blowpipe on charcoal, a white infusible mass is produced, which, when moistened with nitrate of cobalt, becomes a pale blue color when strongly heated.

3. Lime, the oxide of the metal calcium, is found in nearly all kinds of stone in combination with some acid, either carbonic, sulphuric, silicic, fluoric, or phosphoric acid, the first two being the most common, and producing the carbonate of lime, the chief component of chalk, limestone, and marble, and the sulphate of lime, which is the constituent of Derbyshire spar, alabaster, gypsum, and selenite. The presence of lime as a carbonate in a mineral is easily detected by treating the powdered specimen with dilute hydrochloric (or other strong acid), when violent effervescence is produced, and a very soluble salt, chloride of calcium, is the result. If the gas which is evolved is allowed to bubble through lime water, the latter immediately becomes milky, which proves the gas to be carbonic acid. Pure lime can be obtained from the carbonate by heating it to redness in a fire for some hours; if it is allowed to cool, and then put into water, considerable heat is evolved, and the stone crumbles down into a pasty mass, the greater part of which is soluble in water. If the solution is left in an open dish exposed to the air, a thin skin of carbonate of lime is formed on the top, from the affinity which the lime has for the carbonic acid in the atmosphere.

When lime exists in a mineral as the sulphate, it will not be acted on by acids, and is insoluble in water, except in a very slight degree. If the sulphate of lime is strongly heated it crumbles into a powder called *plaster of Paris*, and when water is added, so as to make it into a paste, it quickly hardens.

A piece of pure lime can be readily detected by the blowpipe. If a small loop, made at the end of a platinum wire, is moistened in hydrochloric acid, and dipped in powdered lime, it will give a red color to the outer flame when heated in the inner flame of the blowpipe, or of a Bunsen's burner.

4. Magnesia, the oxide of the metal magnesium, is found in minerals in the form of carbonate, sulphate, and silicate, but chiefly as the carbonate, as in the dolomite of magnesium limestone, of which it forms an important ingredient. If a piece of this stone is reduced to powder, and treated with dilute sulphuric acid, the carbonate of lime which is present will be separated as an insoluble sulphate, and the sulphate of magnesia will be found in the solution. If the solution is filtered off, and treated with solutions of chloride of ammonium (sal-ammoniac), ammonia, and carbonate of ammonia (smelling salts), the latter being added gradually until effervescence ceases, a white crystalline precipitate of phosphate of magnesia will be formed on the addition of a solution of phosphate of soda.

5. Potash or potassa, the oxide of the metal potassium, is a component of several rocks and minerals. It is not easy to detect its presence in a compound without an elaborate process of separating the other constituents. If the solution in which a precipitate of phosphate of magnesia has been produced (as before mentioned) is filtered, and some of the clear liquid placed on a glass with a little hydrochloric acid and bichloride of platinum, a yellow granular precipitate is obtained by stirring with a glass rod, if potash is present in any considerable quantity. Salts of potassium give a violet tint to the blowpipe flame if moistened with hydrochloric acid.

6. Manganese is found in minerals, as the oxide of the metal of that name. Its presence may be detected in an acid solution of a mineral by treating it with hydrosulphate of ammonia, which produces a flesh colored precipitate, provided no iron is present. Ammonia or potash throws down a white precipitate, which becomes brown on exposure to air. Salts of manganese impart a violet color to a bead of borax, heated on platinum wire in the blowpipe.

7. Iron is a common ingredient of all stones and minerals, to which it imparts many of their varieties of color from a light yellowish brown to a dusty red. It is never found in a pure state, but generally as an oxide or sulphide. When there is a salt of iron in a solution a white precipitate is obtained when ammonia or potash is added, the precipitate changing to green or brown by exposure to air. If a solution is neutral or only slightly acid, a drop of the ferrocyanide of potassium (yellow prussiate of potash) will give a precipitate of prussian blue.

Having considered the character of the simple substances which enter into the composition of building stones, we now proceed to examine in detail the several varieties of stone found in the earth, with regard to the proportions in which these substances combine to form them, and also the chemical and other properties which they possess.

Building stones may be classed under one or other of five distinct heads, according to their chemical composition and other characteristics—namely: 1, Granites; 2, Sandstones; 3, Limestones; 4, Magnesian limestones; 5, Slates.

Granites are stones which have undergone a complete change in their original character from having been reduced by intense heat to a molten condition, in which state they have often been forced up through the crevices in overlying rocks, on the top of which they have cooled into a solid and compact mass. Many of the great mountain ranges in various parts of the earth consist of some kind of granite. In these rocks we find a combination of several perfectly distinct minerals, possessing widely different characteristics as regards their composition, hardness, and durability. The most important of these minerals are *quartz*, *feldspar*, *mica or tale*, and *hornblende*—two or more of which are strongly united together to form the solid mass of granite, but each of which can be distinctly seen and separated from the rest of the mass.

The mineral *quartz*, which is found in large quantities in all the older and igneous rocks, is a crystalline form of pure silica, the crystals being six-sided prisms with pyramidal terminations. This is mostly found colorless, but sometimes has a rosy tint, arising from the presence of a small quantity of iron oxide in its composition Quartz is the hardest substance in the composition of granites, their durability as building stones depending very much on the preponderance of this mineral, as it is not affected by any of the ordinary acids, and is only soluble by boiling in strong solutions of caustic alkalies. Its specific gravity is 2·6, water being taken as unity. It scratches glass very readily, and cannot itself be scratched by the hardest steel.

Feldspar is a compound mineral of considerable hardness, but varying greatly in the proportions of simple substances which it contains. It crystallizes in the form of a doubly oblique prism. The kind which is usually found in granite is *potash feldspar*, of which the color is white, gray, or red, according to the proportion of iron oxide it contains. Its chemical composition is sixty-five per cent. of silica, eighteen per cent. of alumina, and sixteen per cent. of potash—it may, therefore, be considered a double silicate of alumina and potash—with a very small proportion of iron oxide and lime. Another kind called *lime feldspar*, contains fifty-six per cent. of silica, twenty-six per cent of alumina, eleven per cent. of lime, four per cent. of soda, and from one to two per cent. of iron oxide, according as the tint is of a light or dark red. *Soda feldspar* contains about nine per cent. of soda, either with or without potash and lime. Those granites in which the feldspar is seen conspicuously in large and distinct crystals embedded in the mass of the stone are called *porphyritic*, and are not considered so durable for work exposed to weather as those in which the particles are smaller and more compact, although, perhaps, of a handsomer appearance when polished—the feldspar, from the nature of its composition, being readily acted on by weather and dilute acids, especially when it contains a large proportion of soda, lime, or iron. The specific gravity of feldspar varies from 3·5 to 2·8. Under the blowpipe it is fusible into a glass.

Mica, or *Talc*, is a soft laminated mineral, which splits up into thin transparent plates. It is found scattered in small quantities throughout the granites, to which it gives a glittering appearance. Its color is variable, according to the proportion of iron which it contains, the tints being white, brown, gray, black, etc., the black variety containing a small proportion of manganese oxide. The chemical analysis of mica gives forty to fifty per cent. of silica, which renders its edges capable of scratching glass, about eight per cent. of potash, and sometimes magnesia, with from sixteen to thirty-seven per cent. of alumina. Before the blowpipe mica fuses readily into a glass or enamel, its specific gravity varies between 2 7 and 3. When the crystals of mica are large and conspicuous in the granite, its durability when exposed to weather is not to be relied upon.

Hornblende is a brown or black prismatic crystal, of about the same hardness of feldspar, and fusible into a glass by the blowpipe. It is a heavy mineral, having a specific gravity of 3, and is composed of about forty-five per cent. of silica, fourteen per cent. of alumina, a considerable proportion of iron oxide, with a little manganese. Its presence in granite adds very much to the compactness and toughness of the mass of stone, which is then termed *Syenite*, a material possessing great hardness and durability.

The specific gravity of granites varies between 2·6 and 5, and the weight per cubic foot from one hundred and sixty to one hundred and ninety pounds, those which consist of small compact grains being usually heavier than those in which the crystals are large and prominent. Most of them are capable of receiving a high degree of polish, which not only enhances their beauty but also increases their power of resisting the action of the weather. Some granites are very absorbent, and will take up from two to three gallons of water to the cubic yard; such kinds are not, therefore, suitable for buildings in exposed situations, from being too open and porous. Those which absorb the least amount of water are generally found to be the most durable.

There is much difference in the strength or resistance to crushing which granites possess; the close-grained and compact kind being capable of bearing a pressure of five tons on the square inch, while others of more open and porous texture will yield to a pressure of three tons on the square inch. It is important, therefore, in selecting granite for building purposes to consider the work it will have to perform, for where it is only required as a decorative material its strength is of but little importance, its color and markings being the chief consideration, many of the most beautiful granites being of too open a character to bear much pressure. Where, however, heavy permanent loads have to be supported the granite must be selected for its hardness and closeness of grain—its color and appearance being only of secondary importance.

Serpentine is a stone that may be classed among granites, from its having been, like them, subjected to fusion. It is found in a variety of colors, and is highly valuable for purposes of decoration, in place of marble, being capable of receiving a good polish. Its texture is very variable, and it is easily acted on by weather and acids. It is composed of thirteen per cent. of silica, forty per cent. of magnesia, with twelve per cent. of water, and the peroxide of iron with lime and alumina in small and varying quantities. This composition seems to indicate that it is a *Dolomite* or *Magnesian Limestone*, which has undergone complete change of character by the action of a melting heat. It possesses only a moderate degree of hardness, and is not crystalline in its formation. Under the blowpipe it is infusible, but gives off water and hardens. The specific gravity of serpentine is about 2·5. It can never be relied upon to sustain any heavy load, and its use must be confined chiefly to decorative purposes.

The relative hardness of the minerals above described is as follows, taking that of the diamond as represented by the number 10—the hardness of quartz is 7, that of feldspar 6, of mica 1·5 to 2·5, of hornblende 5 to 6, and of serpentine 3.

There are other igneous rocks closely allied to granite, of which feldspar forms the chief ingredient; among these we will mention *Porphyry* and *Basalt*, each of which is a compact mass of feldspar, the former having large crystals of feldspar dispersed through it, and the latter having, mixed up with its substance, crystals of a mineral termed *Augite*, which contains fifty-three per cent. of silica, twenty-two per cent. of lime, five per cent. of magnesia, and seventeen per cent. of protoxide of iron. It is a fusible mineral under the blowpipe, and has a hardness equal to that of hornblende. All this class of rocks is susceptible of a high degree of polish.—*Brick Review.*

GLYCERINE BAROMETERS.

FOUR Jordan glycerine barometers are now in use in or near London, viz., one at Kew, one in the Museum of Practical Geology, one at South Kensington, and one in the *Times* office. The enormous scale of the barometer enables changes scarcely visible in the mercurial instrument to be detected with ease. The correction for temperatures is made by the following formula:

$$H = A - [0{\cdot}000303 + (t - 32 \text{ deg.})\, h].$$

in which A=observed height of column in inches; t=temperature in degrees Fahr., H=corrected height at 32 degrees Fahr.; and 0·000303=expansion of glycerine for one degree Fahr. It is added that the specific gravity of glycerine is 1·2608 at 60 degrees Fahr.

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